A COMPARATIVE STUDY OF THE VISUAL OUTCOMES OF PENETRATING KERATOPLASTY AND DEEP ANTERIOR LAMELLAR KERATOPLASTY IN KERATOCONUS

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CERTIFICATE

This is to certify that the thesis entitled **"A COMPARATIVE STUDY OF THE VISUAL OUTCOMES OF PENETRATING KERATOPLASTY AND DEEP ANTERIOR LAMELLAR KERATOPLASTY IN KERATOCONUS"** is the original work of **Dr. Subathra.GN** and was conducted under our direct supervision and guidance at Aravind Eye Hospitals and Postgraduate Institute of Ophthalmology, Madurai during her residency period from May 2012 to April 2015.

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This dissertation is submitted to the **Tamil Nadu Dr.M.G.R Medical University**, Chennai in partial fulfillment of the rules and regulation for the award of **M.S. Ophthalmology (Branch III)** to be held in April 2015.

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INTRODUCTION

Keratoconus is a non-inflammatory disorder characterized by ectasia of the cornea, most commonly the central or inferior portion of the cornea, with eventual progressive protrusion and corneal thinning.

The cornea, a clear transparent structure, is the major refractive surface of the eye. The corneal thinning and protrusion in keratoconus induces irregular astigmatism and myopia causing mild to marked visual impairment. The prevalence of Keratoconus is about 50 to 230 per 100,000 population.[1] Keratoconus usually has its onset at puberty and progresses until third to fourth decade of life[1] when it usually arrests.

Keratoconus is reported to have bilateral involvement in over 90 percent of patients, with asymmetric presentation. It usually affect one eye more than the other, with keratoconus becoming apparent in fellow eye after many years.[2] The term “forme fruste keratoconus” is used for less affected fellow eye, where there are certain topographic changes with no clinical findings.

History of Keratoconus

The term "Keratoconus" derives from the Greek words Kerato (cornea) and Konos (cone). Early description of keratoconus was made in 18th century by Mauchart, describing the condition as staphyloma diaphanum[3,4] , but it was a British physician John Nottingham first described and distinguished keratoconus from other types of corneal ectasia.[4,6] The disorder acquired its current name from the Swiss ophthalmologist Johann Horner who published a thesis entitled " *On the treatment of keratoconus"* in 1869.[7] The early treatment of keratoconus consist of using silver nitrate and cauterizing the ectatic area of cornea and it was in 1888, Eugene Kalt, a French ophthalmologist, described the first application of contact lens using a crude glass shell to compress the conical apex in keratoconus.[8]

ETIOLOGY AND PATHOGENESIS

Over the years, many theories have been put forward for keratoconus, but the exact cause still remains an enigma. Keratoconus is a complex condition where both genetic and environmental factors are considered for the etiology of the disease. An Autosomal dominant transmission with incomplete penetrance has been proposed. Teng[9] considered keratoconus as a disease of ectodermal layer of cornea with the stroma being secondarily affected.

Sawagamchi et al in their study showed an increase in lysosomal enzymes in basal epithelium of cornea in keratoconus patients.[10] This may lead to corneal stromal degradation causing ectasia of cornea.

Biochemical and immunohistologic studies of keratoconus corneas suggest that the derangement of proteolytic enzymes like increase in proteases or decrease in proteinase inhibitors may lead to loss of corneal stroma. Observations of the corneal proteinase inhibitors such as a_1 proteinase inhibitor and a_2-macroglobulin, confer further support on the hypothesis that in keratoconus there is aberrant degradation process of cornea.[10,11]

Mechanical trauma and eye rubbing has been recognized as a risk factor for Keratoconus since 1956 by Ridley[12]. In uncontrolled studies on keratoconic

patients, the prevalence of eye rubbing has ranged from 66 to 73 percent.[13] There are also some reports regarding the association between acute hydrops and vigorous eye rubbing.[14-16]

The exact mechanism by which eye rubbing may cause keratoconus is unknown. It has been proposed that interleukin-1 (IL-1) plays a major role in the pathogenesis of keratoconus. Interleukin-1(IL-1) is produced by corneal epithelium and endothelium, which causes keratocyte death and upregulates the growth factors. IL-1 thus plays a role in the regulation of corneal cell proliferation, differentiation and death. Thus IL-1 released during eye rubbing from corneal epithelium or endothelium causes decrease in stromal mass by causing decrease in keratocytes.[1]

Bawazeer et al reported that eye rubbing was the main significant predictor among other different risk factors of keratoconus like age,sex, race, family history, Marfan syndrome, Down syndrome, ocular trauma, collagen vascular disease, mitral valve prolapse, pigmentary retinopathy and corneal degeneration and dystrophy.[17]

HISTOPATHOLOGY:

Mostly all the layers of the cornea may be involved in the pathologic process of keratoconus.. In the epithelium there may be degeneration of its basal cells causing breaks within and downgrowth of epithelium down into Bowman's membrane and accumulation of ferritin particles within the basal epithelial cells. Changes in Bowman's layer may include breaks filled by eruptions of underlying stromal collagen, z- shaped interruptions may be due to separation of collagen bundles and reticular scarring. Compaction and derangement of fibrillar architecture may occur in the anterior stroma. There is decrease in the number of collagen lamellae and degenerating fibroblasts and keratocytes may be seen. Descemet's membrane is rarely affected except for breaks seen in acute hydrops. The corneal endothelium is usually unaffected but endothelial cell pleomorphism and polymegathism may also be manifested with greater change and damage occurring at the base of the cone than at the apex.

CLINICAL FEATURES

The clinical course of keratoconus is highly specific. Although keratoconus can present in any age group, it mostly affects patients in their late teens or early twenties. The condition is almost always progressive but the rate of progression and ultimate severity are quite variable. The usual symptoms are deterioration of visual acuity, frequent changes in refraction, and the visual acuity not refractable to 6/6. Glare, distortion of images, monocular polyopia, and ghosting of images are also usual symptoms.

FEATURES:

1. **External signs**

   - Munson's sign : the indentation of lower lid caused by the protruding apex of the keratoconus. It is seen in advanced cases of keratoconus.
   - Rizutti's sign: A light reflex projected from the temporal side will be displaced beyond the nasal limbal sulcus when high astigmatism and steep curvatures are present.

2. Slit lamp Findings

- Thinning of corneal stroma
- Vogt striae : Vertical stress lines in the deep stroma and descemet's membrane that tend to disappear on pressure.
- Fleischers ring: Deposition of iron in basal epithelial layer in a ring shape at the base of the conical protrusion.
- Corneal apical scarring
- Prominent corneal nerves
- Hydrops: An acute rupture in descemet's membrane causes imbibition of aqueous into corneal stroma causing it to swell and cause acute reduction in vision.

3. Retro illumination signs

- Scissoring reflex on retinoscopy
- oil droplet sign (charleaux)

4. Photo Kerotoscopy

- there is compression of mires especially inferotemporally or centrally
- irregular mires-most common egg shaped mires

5. Video keratography signs

- Localised increase of surface power which is usually present in the inferior or inferotemporal cornea.
- Inferior superior diopter asymmetry
- Relative skewing of steepest radial axis above and below the horizontal meridian

The main stay for early detection, diagnosis and tracking of ectasia remains videokeratography. Corneal topography by way of which measurement of the corneal shape are recorded may be done by several ways. These includes the conventional reflection based topography systems (keratometry, photokeratoscopy, videokeratoscopy) and the recent projection based systems (rasterstereography, laser interferometry etc). The latest technology for analysis of corneal topography is the Scheimpflug photography which provides reliable measurement of anterior and posterior corneal elevation.

For screening patients for keratoconus ,Rabinowitz has suggested four quantitative videokeratographic indices [18]

- A keratometric value greater than 47.2 D of central corneal diameter is suggestive of keratoconus.
- The asymmetry of inferior–superior diopter (I-S value) over 1.2,
- Sim-K astigmatism value greater than 1.5 D, and
- KISA percent incorporates the K and I-S values with a measure, quantifying the regular and irregular astigmatism into one index.

  KISA percent= K x I-S asymmetry x AST (degree of regular corneal astigmatism) x SRAX x 100

  This index is highly sensitive and specific in differentiating the normal from keratoconic corneas. A value of greater than 100 percent is highly suggestive of frank keratoconus, and the range from 60 to 100 percnt represents keratoconus suspects.

Other red flags or indices associated with possible signs of early ectasia with the Orbscan are[19]

- Pachymetry reading with a thinnest point less than a certain threshold (470-500 microns).
- Posterior float greater than 50 microns.

- High irregularity indices at the 3mm and 5mm zones.
- A minimum peripheral corneal thickness that in not at least 20 microns greater than the central cornea.
- The overall correlation of the highest/thinnest point coinciding on the anterior ,posterior and pachymetry maps.

For screening purposes, it is claimed that pentacam anterior elevation values between +12 to +15 microns (above reference sphere) are suspicious for ectasia and anterior elevation of more than +15 microns is indicative of keratoconus.[20]

Wavefront sensing:

It has been established that wavefront data can further enhance our topographic diagnostic abilities. Maeda et al showed that wavefront aberrometer may provide additional clues for the detection of early corneal ectasia.[21] An increase in the total higher order aberrations was noted in keratoconus and attributed to the corneal shape. Coma like aberrations were dominant and increased in the keratoconus eyes. Moreover subsets of corneal ectasia have been shown to produce unique wavefront profiles . Pepose and Applegate demonstrated that patients with pellucid marginal degeneration could be differentiated from keratoconus based on wavefront data.[9]

CLASSIFICATION OF KERATOCONUS:

Classically, keratoconus has been classified based on the morphology into:

Nipple **–**nipple cone is a small ,near central cone, less than 5.0mm in diameter.

Oval **–** the oval cone is the most common type of cone found, especially in advanced keratoconus. Most commonly the ectasia involves the inferior cornea causing inferior mid-peripheral steepening. The diameter of the cone >5 mm.

Globus **–** globus cone is a large cone often affecting nearly three quarters of the corneal surface, more than 6.0 mm in diameter.

Based on corneal curvature(keratometry)

Mild - <48 D

Moderate – 48-54 D

Severe - >54 D

Krumeich classification of keratoconus:

severity	Km(Sim K) (Diopters)	Thickness (microns)	Spherical equivalent	Cornea
4	>55	<200	Not measurable	Central scar
3	54-55	200-400	>-8D	No central scar
2	48-53	400-500	-5 to -8D	No central scar
1	<48	>500	<-5D	No central scar

MANAGEMENT AND TREATMENT OF KERATOCONUS

Keratoconus management varies depending on the disease severity. In initial stages the refractive error are managed with spectacles, later mild to moderate cases can be managed with contact lenses, and severe cases needed surgical treatment which include intra-corneal rings segments, corneal cross-linking, intra-ocular lens implants and keratoplasty.

Spectacles

In the initial stages of keratoconus, the refractive error due to ectasia of the cornea can be managed by spectacles. But when the disease progresses, adequate visual acuity cannot be achieved with spectacles because of the development of irregular astigmatism. This irregular astigmatism occurring when the disease progresses can be managed better with contact lens than spectacles.

Contact lenses

Contact lens is the common treatment option for early to moderate cases of keratoconus. Contact lenses improve vision by creating a smoother cornea by filling the gap between the irregular corneal surface and inner surface of lens with the tear fluid. The various contact lenses for keratoconus are rigid gas

permeable lenses ,hydrogel, silicone hydrogel, hybrid lenses, Rose K lenses and sclera lenses.

Rigid gas permeable lenses

Rigid gas permeable (RGP) corneal lenses are the most commonly used contact lenses for keratoconus. The RGP lenses provide better vision by correcting the irregular astigmatism occurring due to ectasia of cornea.

In mild to moderate keratoconus, the lens diameter selected is usually 7.5 to 8.5mm. The smaller size of the lens provides a steeper fit to accommodate the cone and used for nipple cone types. For oval or globus type cone which involves the periphery of the cornea also, a larger and flatter lens are required.

Three fitting techniques of gas permeable contact lenses, including apical clearance, apical touch and three-point touch, are used for keratoconus. In this three point touch technique is most preferable technique.

In apical clearance technique the lens is supported onto the paracentral cornea, directed off the apex of the cornea, thus there is clearance of the apex of the cornea; but due to poor visual acuity and progression control ,this technique is no longer used at present.

In apical touch fitting technique the support to the lens is mainly provided by the apex of the cornea, so that the central optic zone of the contact lens touches the central portion of the cornea. .Though it provides good visual acuity and control of keratoconus progression, this technique is limited due to corneal scarring.

The three point touch contact lens design is the most ideal technique and is better than other techniques of contact lens fitting for keratoconus patients. In this technique there is a slight central touch due to steep base curve of the lens causing thinning of fluorescein at the corneal apex and slight touch mid-peripherally at 3 and 9'0 clock along the horizontal meridian. Thus along the horizontal meridian there is a three point lens touch. This lens should be individualized by checking the fit and modify accordingly since each individual cone is different.

Piggy back lenses, in which gas permeable rigid lenses are worn over soft lenses has also been used for keratoconus. The gas permeable contact lens provide better visual acuity, while improved wearing comfort is provided by the soft contact lens.

Hybrid contact lenses, have been developed which are lenses with rigid gas permeable optic zone surrounded by a soft skirt to ensure a comfortable fit. These lenses are not widely accepted because they don't provide improved visual acuity and comfort than the gas permeable contact lenses and hybrid lenses are expensive.

Rose K contact lenses

Rose K contact lenses are newer keratoconus lens, with complex computer generated peripheral curves based on precollected data .The Rose K lenses are customized for each eye individually and it takes into account of the conical shape of the cornea. Rose K lenses provide better oxygenation of the cornea also.

The system incorporates triple peripheral curve system standard, flat, and steep in order to achieve ideal edge lift of 0.8mm. Available base curves of Rose K lenses are : 4.75 to 8.00mm and diameter of 7.92 to 10.00mm.

Soper lenses are one other lens design for keratoconus. Soper lenses have a bicurve design with a steep central curve for the cone and a flatter peripheral curve for the peripheral cornea.

Sclera lenses provides more stability and comfort since it covers a greater proportion of the surface of the eye. They have more wearing comfort and can be used in rigid lens intolerant patients.

Surgical Procedures :

- The various surgical options for keratoconus are:
- Intracorneal ring segment insert
- Corneal collagen cross linkage
- Thermokeratoplasty
- Epikeratophakia
- Toric phakic intraocular lenses
- Corneal transplantation
    - Penetrating keratoplasty
    - Deep anterior lamellar keratoplasty

Intrastromal corneal ring segments:

A recent surgical alternative to corneal transplant for keratoconus is the insertion of intrastromal corneal ring segments(ICRS). ICRS initially used to correct myopic refractive error, now used for ectatic corneal disease. ICRS are placed in the peripheral corneal stroma at approximately two third depth,

outside the central optical zone. They correct the refractive error by reshaping the anterior corneal surface.

The first generation design of ICRS was referred to as the 360^0 intrastromal corneal ring. The current design consists of two polymethyl methacrylate segments, each with an arc length of 150^0. Each intacs segment has a hexagonal cross section that lies along a conic section. The two segments are designated as clockwise and anticlockwise to correspond to their orientation during insertion in to the intrastromal tunnel. These inserts are inserted through a small radial incision in the cornea and are placed at the depth of two-third of the corneal thickness.

Intacs change the arc length of the anterior corneal curvature. The ring segment causes local separation of the corneal lamellae, which results in shortening of the corneal arc length. This has a net effect of flattening the cornea, thereby correcting the myopia. Increasing the thickness of ICRS causes greater degree of local separation and increased corneal flattening. Thus the degree of corneal flattening is directly related to thickness of Intacs. Rings are available in thickness varying from 0.25 mm to 0.45 mm.

Intacs and Ferrara are the main two types of intrastromal corneal rings available. Intacs are flatter and less centrally placed than the ferrara rings. Some of the complications of intrastromal rings are migration or extrusion of the rings, penetration of the rings into the anterior chamber intraoperatively and post operative infection

Corneal cross linkage (CR3):

Crosslinking of the cornea is an approach which increases the stability of the stromal tissue mechanically and biochemically. The idea of crosslinkage to treat Keratoconus was first proposed in Germany in the 1990s by a research group at Dresden Technical University mainly to delay the progression of Keratoconus. Thus collagen crosslinking helps to block the progression of Keratoconus temporarily mainly in the refractive phase. Crosslinking freezes stromal collagen, increasing the biomechanical stability of the cornea.

Collagen X-linking creates additional chemical bonds by means of photopolymerization in the anterior stroma. Riboflavin, when activated by ultraviolet A, creates free radicals which induce new chemical bonds.

The important preoperative parameters are:

- To know the progression of keratoconus (progression should be defined as an increase in maximum keratometry of 1diopter in one year)
- Corneal pachymetry of 400 microns meter minimum.
- Slit lamp evaluation to rule out any corneal scarring.

Method of application:

The central 7.0 to 9.0mm of corneal epithelium is removed by mechanical debridement, without disturbing the sub-epithelial components. This helps in better penetration of riboflavin through the stroma and achieves a high level of UVA absorption . As a photosensitizer,0.1 percent riboflavin solution (usually containing 20% dextran) is applied to the cornea every five minutes for 30 minutes before irradiation thus allowing sufficient saturation of the stroma. Using a wavelength of 370nm UVA irradiation is commenced, at surface irradiance of 3.0Mw/cm^2 for 30 minutes. Riboflavin solution is applied every two to three minutes throughout the irradiation phase to keep the stromal surface moist and stromal thickness above 400 microns. After the procedure, bandage contact lens applied after a combination of steroid and antibiotic are administered. Bandage contact lens is removed after full corneal

reepithelialization occurs. Alternatively it can be performed transepithelially. In “Epi-on” procedure riboflavin is applied without the removal of the corneal epithelium and the penetration of riboflavin is aided with the help of paracaine.

The changes in the cornea induced by crosslinking includes the change in curvature of the cornea and delay in progression of ectasia evidenced by videokeratography. A reduction in some higher order aberrations has been demonstrated after crosslinking suggesting improved symmetry and homogeneity of the anterior corneal surface topography.

Some of the complications of corneal crosslinking are corneal scarring (diffuse subepithelial opacification), stromal haze, infective keratitis and diffuse lamellar keratitis.

For thinner corneas hypotonic riboflavin without dextran is recommended. Accelerated C3R may replace the standard procedure as recent results have shown the advantage of higher irradiance and shorter duration of treatment with equal efficacy and safety.

Thermokeratoplasty

In the mid-1970s, a new surgical technique of application of heat at the apex of the cone gained popularity. This thermal therapy due to adverse effects like corneal scarring and poor visual outcome was later abandoned.

Epikeratophakia:

Kaufmann described a newer technique, epikeratophakia in 1980. In this procedure the corneal epithelium is removed from the host and a cryolathed lenticule from the donor cornea is placed onto the corneal stromal bed and sutured. Due to adverse effects like failure of re-epithelisation, inflammation, interface haze, opacification and poor visual outcomes, they are less favored than keratoplasty surgery.

Phakic intraocular lens implantation:

Phakic intraocular lenses are artificial lenses implanted in the anterior or posterior chamber of the eye in the presence of natural crystalline lens to correct refractive error. Patients who have high refractive errors and/or thin corneas, are unsuitable for corneal refractive surgery. For such patients, lenticular refractive surgery is an option. Phakic intraocular lens implantation has been recently considered for keratoconus patients. Phakic intraocular lens

helps to correct the high myopia and astigmatism in keratoconus without altering the progression of the disease. Phakic intraocular lens implantation can be combined with other surgery like INTACS for better outcomes in keratoconus patients.[22] Phakic lens correct the major part of refractive error especially high myopia, and INTACS is used to correct the residual error. Refinement of intraocular lens implantation and positioning will aid in future management of keratoconus patients.

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EVOLUTION OF CORNEAL GRAFT SURGERY

Early in 1824, F Reisinger successfully performed first corneal graft by replacing opaque human cornea with transparent animal cornea.[23] The first successful penetrating keratoplasty was performed by Edward Konrad Zirm in 1905.[24]

Lamellar keratoplasty was first suggested in 1830 by von Walther, and further improved by Von Hippel and Filatov. But later Fuchs reported poor results on a series of 30 lamellar grafts using tissues from animal cornea.[25]

The surgical techniques of lamellar keratoplasty was further developed by Paufique in 1940.[26] McCulloh[27] described lamellar keratoplasty using full thickness donor tissue, while Malbran described peripheral lamellar dissection with central peeling in Keratoconus.[28]

Anwar in 1974 described deep dissection under direct visualization in a potential cleavage plane between stroma and descemet's membrane. Anwar was the first to describe deep dissection baring the descemet's membrane and used full thickness donor tissue after removing the donor descemet's membrane and endothelium, in lamellar keratoplasty.[29,30] Barraquer in 1964 introduced the microkeratome which improved the lamellar dissection .[31,32]

Archila again described deep lamellar dissection up to the descemet's membrane in the 1980s.[33] Archila used intrastromal air injection and spatula dissection to facilitate access to the descemet's membrane without perforation. Price and Rostron[34] described similar technique later, with Sugita[35] elaborating hydrodelamination and spatula delamination.

Melles described deep lamellar dissection facilitated by a special semi-sharp spatula in a closed manner.[36,37] The "Big Bubble" technique of Anwar and Teichmann for deep lamellar dissection has gained popularity in recent times.[38-40]

PENETRATING KERATOPLASTY

Penetrating keratoplasty is the corneal transplant procedure in which full thickness diseased host corneal tissue is excised and replaced with full thickness healthy donor cornea.

Keratoconus is one of the main indications for keratoplasty. Rabinowitz[1] reported that around 10-20% of the patients of keratoconus will require a corneal graft in their life time. With recent improvement in the surgical technique of lamellar keratoplasty, deep anterior lamellar keratoplasty has been considered as an acceptable alternative by many surgeons for keratoconus. However, PKP still remains the treatment of choice in many advanced cases with deep scar in Descemet's membrane, when corneal thinness makes lamellar dissection difficult, or a second line treatment following DALK procedure when there is intraoperative perforation of Descemet's membrane. The prognosis of PKP in patients with Keratoconus is excellent compared to that of other diseases.[39-42]

PREOPERATIVE EVALUATION:

- Evaluation of visual potential
- Ocular surface abnormality

- Intraocular pressure
- Ocular inflammation
- Corneal vascularization

INVESTIGATIONS

- Refraction
- Tear film status
- Keratometry
- Gonioscopy
- Pachymetry
- Specular Microscopy
- Videokeratography
- Slit scanning (Orbscan) and Scheimpflug(Pentacam) Imaging

INSTRUMENTATION FOR CORNEAL TRANSPLANT SURGERY

Eye speculum:

The speculum should be light weight, have minimum extraneous parts and avoid undue pressure over the globe. A wire lid speculum such as Kartz-Barraquer or Maumenee-park speculum can be used.

Globe supporting rings:

Flieringa ring of stainless steel is commonly used. They are available in 11 sizes from 12-22mm. McNeill-Goldman ring can also be used.

CORNEAL TREPHINES:

The first corneal Trephine was developed byVon Hippel, which was motorized (wind-up) and became the prototype for future devices

Trephine is a stainless, sharp, cylindrical blade, which creates a circular corneal incision, without causing much damage to corneal tissues.Trephines help to reduce post operative astigmatism after corneal transplantation.

TYPES:

- Conventional circular cutting trephines
- Single point cutting trephines
- Combination trephines
- Non-contact trephines (Lasers)

Conventional circular trephines:

Hand held trephines: They are the most commonly used trephines available in sizes from 3 to 17 mm. They are usually attached to a handle for stability and control. Examples are Castroviejo trephine, Grieshaber-Franceschetti trephine.

Mechanized corneal trephines:

The cutting blade of this type of trephine is driven by a motor present in the main body. Microkeratron (Hans Geuder, Heidelberg), commonly used mechanized trephine. Disadvantage include corkscrew edge effect in the corneal stroma.

Suction Fixation Corneal Trephines:

These trephines have been devised to obtain a perpendicular cut in the recipient cornea. They consist of an outer corneal suction ring for fixation and a inner circular cutting blade. Hessburg-Barron trephine is a prototype, which has a spring-loaded disposable syringe creating the required negative pressure. It is available in diameters of 6.0-9.0 in 0.5 increments.

Special Purpose trephines:

Used in cases of optical zone lacerations in the recipient cornea. The lacerated cornea is supported from behind by protective plate and an upper plate above so that cornea is securely placed between two plates.

Skin biopsy punches: useful in harvesting of small patch grafts used for tectonic purposes in cases of impending/frank perforation.

Single point cutting corneal trephines:

They were designed to decrease corneal torsion. In these trephines, fixation takes place at the limbus or on the sclera thereby reducing the corneal distortion. Example- Leiberman single point cutter.

Combination corneal trephines:

They combine the best features of the previous trephines. Hanna trephine system has got a circular razor-cutting blade and incorporates many of the salient features of single point cutting trephines.

Cutting blocks:

An ideal cutting block attempts to approximate the corneal shape and reduces the tissue distortion. The various cutting blocks available for corneal grafting are paraffin block, Teflon block , polycarbonate and nylon blocks. But now, Teflon blocks with different radii of curvature are available.

Corneal endothelial punches:

They are used to cut donor button from endothelial side. The main advantage of corneal punch is to have a more vertical cut without beveling. Some of the corneal punches are:

- Cottingham corneal punch
- Troutman corneal punch
- IOWA PK Press corneal punch
- Lieberman Gravity-action punch
- Rothman-Gilbard corneal punch

Cutting and Grasping instruments:

Cutting instruments like blade breaker, diamond knife , corneal scissors are used. Corneal scissors are used to complete the trephination of the host cornea after creation of the circular cut following anterior chamber entry. Curved vannas scissors can also be used for the same. Grasping instruments like toothed and non toothed forceps are used.

SURGICAL TECHNIQUE

Penetrating Keratoplasty can be safely done under local or general anaethesia.[43] General Anesthesia is usually used for pediatric cases and uncooperative patients.

Good exposure of the eyeball done with the eye speculum. Barraquer wire speculum is commonly used speculum.

Scleral supporting rings are used to provide ocular rigidity and prevent sclera collapse during the surgery. These rings are sutured to the sclera with silk or Vicryl sutures with 50 percent of the thickness of sclera bite.

MARKING OF THE HOST CORNEA

Marking of the host cornea is done first with proper centeration of the graft. Using calipers, the horizontal and vertical diameters of the recipient cornea are measured and size of the graft determined. Normally size of the host cut varies from 7 to 8 mm. Small Graft may lead to postkeratoplasty astigmatism and large graft may lead to immunological rejection.[44] In case of keratoconus, the whole of the cone should be included in host cut. After marking geomentric center of the cornea, radial keratotomy markers can be used to guide the suture placement.

PREPARATION OF DONOR CORNEA:

It is better that the donor corneal button prepared before the recipient cornea. The graft size depends on planned diameter of the host cut. The graft host disparity depends on various factors. Normally 0.25-0.5mm oversized donor corneal button used. In Keratoconus, the graft host disparity should be less to compensate for the myopia.

Corneal graft punched from the endothelial side has less damage and cleaner cut than the preparation from epithelial surface. But graft cut from the endothelial side are smaller by 0.2 mm compared to epithelial side cut.[45,46]

Donor graft can be harvested from the corneoscleral button with the help of trephines or corneal punches. The donor button is placed on the cutting block with endothelial side up and cut with hand held trephine held perpendicularly. Uniform pressure given and cut by punching rather than rotating the blade to minimize damage. The corneal endothelial punch makes a sharp vertical cut with more accurate centration.

Non mechanical laser trephination using excimer laser can also be performed from the epithelial side on the cornea.

TREPHINATION OF RECIPIENT CORNEA

The size of recipient corneal cut depends on many factors like diameter of cornea, extent of the disease.

Trephining with hand held Trephines:

The standard trephine has a circular blade on a handle eg, Castroviejo trephine. The handle has an internal obturator, which limits the depth of the cut. The trephine is held perpendicular to the cornea with proper centration and rotated between thumb and forefinger. Partial thickness cut up to pre descemet's preferred to prevent collapse of the globe. Then anterior chamber entry made with a blade. Corneal scissors used to complete the cut.

Trephining with the suction trephine:

Suction trephines create a sharper, deeper and more perpendicular incision. This trephine consists of body and a blade assembly.

Body contains- Vacuum chamber, Syringe with a spring- loaded plunger, connected to vacuum chamber by silicon tube.

Blade contains- blade, cross hair for centration, and four plastic spokes for turning the blade.

Trephine is placed on the cornea, with the cross hair aligned with the centration mark on the cornea. Trephine is pressed and plunger is released. After suction has been obtained, the cornea is cut by turning the spokes clockwise up to the descemet's membrane. The anterior chamber then entered with the blade and cut is completed with corneal scissors.

Non-mechanical Trephination of the Cornea:

Trephination can also be performed with excimer laser(193 nm) producing less distortion of corneal cut margins.

GRAFT PLACEMENT AND CHAMBER FORMATION:

The anterior chamber of the host is filled with the viscoelastic, and donor graft is brought to the field with a graft holder. The edge of the button is placed on the inferior limbus and rest of the graft is positioned.

SUTURING:

It is first necessary to place four cardinal sutures first. The first suture placed at 12 o' clock position followed by a suture at 6 o' clock. The depth of the suture is usually 90% of the corneal thickness, anterior to Descemet's membrane. Avoid through and through suturing, because of the chance for endothelial damage[48] and subsequent infection. The 3 and 9 o' clock sutures are placed similarly. The rest of the sutures may be put as interrupted sutures, single running suture or double running suture. None of the suturing technique have proved superior in astigmatism.

Interrupted sutures are suitable for children, vascularized and thin corneas for selective removal when needed. There are 3 types of single running suture - torque, anti-torque or no torque techniques. The torque pattern rotates the corneal graft counterclockwise by 0.7+/- 0.1 mm, the antitorque pattern

rotates the cornea clockwise by 0.7 +/- 0.1 mm, and the no torque pattern produces no rotational effect.

The knot ends are trimmed and buried in to the host or donor tissue. Knots buried in the host tissue may stimulate vascularisation.

After completion of the suturing, the wound is tested for tightness and leakage by fluorescein staining.

COMPLICATIONS:

The complications can be intraoperative or postoperative

INTRAOPERATIVE COMPLICATIONS

1. Improper trephination
    - Eccentric host trephination: Improper centration of the graft give rise to high postoperative astigmatism.
    - Irregular trephination: blunt trephines can cause irregular cuts.
    - Retained Descemet's membrane
2. Damage of the donor button
3. Inversion of the corneal button, suturing with endothelial side facing upwards.
4. Excessive bleeding

5. Injury to lens-iris diaphragm
6. Iris incarceration in suture bite.
7. Wound leak

POSTOPERATIVE COMPLICATIONS

1. **Wound leak and shallow anterior chamber:**

   The site of leak can be checked with fluorescein dye test (siedel's test). The common causes for wound leak are broken/ loose sutures, suture through necrotic tissue, excessive gap between sutures, unequal thickness of graft and host.

   Management: If anterior chamber is flat with wound leak, immediate surgical repair needed. If anterior chamber was formed, then pressure bandage or bandage contact lens can be tried.

2. **Epithelial defect:**

   Survival of the corneal graft is critically dependent on an intact epithelial barrier. Persistent epithelial defect is considered when 2-4 days passed without signs of healing. A persistent epithelial defect may lead to graft ulceration, stromal melting and graft failure.[48] Risk factors for persistent epithelial defects are ocular surface disorders, lid abnormalities, neurogenic, epitheliotoxic drugs, damage donor epithelium, trauma.

The management of epithelial defect includes pressure patching, bandage soft contact lens, permanent or temporary tarsorraphy and limiting medication toxic to epithelium. Amniotic membrane transplantation can be done for severe cases.

3. **Wound Dehiscence:**

PKP comprises full thickness 360° surgical wound and creates permanent weakness of the eyeball. Traumatic graft dehiscence can occur anytime after PKP, in literature it has been reported from 3 days to 33years.[49,50] Some of the causes of wound dehiscence are trauma, infectious keratitis, spontaneous wound separation and suture failure.

The incidence of traumatic globe rupture after PKP was reported as 0.6-5.8%.[51]

4. **Suture Related problems:**

- **Exposed suture knots:**

May cause foreign body sensation, giant papillary conjunctivitis, stimulate corneal vascularization. May act as a nidus for microbial infection. Can be managed by suture rotation or replacing the exposed suture.

- **Tight/loose sutures:**

  Tight suture can cause persistent epithelial defect and high degree astigmatism. Loose suture site may become a focus of infection. Tight or loose sutures should be replaced in the immediate post operative period.

- **Suture related infections:**

  May occur due to exposed suture, use of soft bandage contact lens and steroids. Suture abscess is a poor prognostic factor for graft survival. Suture abscess should be treated rigorously. Suture roof should be debrided and material send for microbiological examination. The patient should be treated with broad spectrum antibiotics until sensitivity is known.

- **Suture related immune infiltrates:**

  It can occur due to immunological reaction to sutures or talc in surgical gloves. It can be differentiated from infectious infiltrate, by multiple infiltrates mainly in host side and not associated with epithelial defect. It can be treated by increasing steroid dose or adding cyclosporine A drops if persistent.

5. **Microbial keratitis:**

The infection can be within the graft or infection along the suture tract of graft-host junction. The incidence of microbial keratitis in corneal graft in developing countries has been reported to be as high as 11.9%.[52] Some of the common causes for the graft infection are donor button contamination, intraoperative complications, persistent epithelial defect and suture related problems.[53] Most common pathogens are gram positive bacteria especially staphylococcus species, followed by gram negative organisms and fungal organisms. Corneal scrapings are obtained for smear and culture sensitivity and vigorous antimicrobial therapy started.[54]

6. **High Intraocular Pressure:**

The factors contributing to high intraocular pressure in the early postoperative period are Residual viscoelastics, uveitis, hyphema, papillary block, forward movement of lens iris diaphragm.[55]

7. **Primary graft failure:**

Corneal grafts that have gross edema with large folds immediately after keratoplasty and which does not have period of clear cornea are considered primary graft failure. The major causes are unhealthy donor cornea, inadequate tissue preservation, and surgical trauma.[56] The

incidence of primary graft failure is less than 5%.[56] Primary graft failure can be prevented by proper donor selection with good endothelium. Once diagnosed, primary graft failure is managed only by regrafting.

8. Urrets-Zavalia Syndrome:

This is characterized by fixed dilated pupil, first described by Urrets-Zavalia after a corneal graft for keratoconus. He also recognized iris atrophy and secondary glaucoma in these patients. Although the etiology is unknown, severe iris ischemia was noted and use of strong mydriatics are thought to be the possible mechanism.

9. Astigmatism:

Astigmatism is the main source of limitation in visual acuity following PKP in a patient with clear graft making the graft optically fail. Possible causes for postoperative astigmatism are donor or host related factors like scarring, thinning, vascularization , improper trephination, eccentric graft, mal alignment of graft, faulty suture technique and depends on wound healing. Astigmatism can be minimized with proper trephination, suturing, suture adjustment or selective suture removal. Astigmatism can be managed by non surgical methods like spectacles or contact lenses. But high astigmatism after removal of sutures should be managed surgically.

The surgical options are Astigmatic keratotomy- manual and femtosecond. Astigmatic keratotomies include relaxing incisions, arcuate keratotomy, wedge resection, T cuts. Arcuate keratotomies performed with femtosecond laser have been found to be effective in reducing postkeratoplasty astigmatism.[57] LASIK has been reported to be effective in reducing post PKP Astigmatism and myopia.[58] Toric IOL's are also used to correct astigmatism[59] and require less manipulation of graft tissue. Frohn et al[61] were the first to describe toric IOL in a patient with cataract for correction of high post keratoplasty astigmatism. But surgically induced astigmatism resulting from toric IOL implantation is the major limitation of the technique.

10. Glaucoma:

Persistent elevation of intraocular pressure not only affects the optic nerve but has a deleterious effect on the corneal endothelium.[61] The major risk factors for late postoperative glaucoma are pre-existing glaucoma, pigment dispersion syndrome, prolonged inflammation, tight and deep sutures, peripheral anterior synechiae, epithelial and fibrous ingrowth, long term use of steroids. Glaucoma is managed medically with topical or systemic anti-glaucoma medications. Surgical therapy is

indicated when either the optic nerve or the graft is threatened by sustained elevation of IOP.

DEEP ANTERIOR LAMELLAR KERATOPLASTY

Deep anterior lamellar keratoplasty is a technique of corneal transplantation in which anterior layers of the cornea are removed preferably upto the descemet's membrane while retaining the posterior layers along with the endothelium.

Although lamellar keratoplasty technique has been known for a long time,[62] due to difficulty in getting smooth interface and technical difficulties limited the popularity of this procedure.[63]

Von Walther was the first to propose Lamellar Keratoplasty in 1830. After that in 1880 Von Hippel, Filatov in 1930[66] and Paufique in 1940 advanced the technique.

In 1999, Melles at al.[37] described a method in which air was injected into the anterior chamber that created a mirror reflex that guide for proper dissection of posterior stroma.In 2002, Anwar et al.[39] modify the technique of air injection by performing about 60-70 percent corneal trephination before injecting the " Big Bubble" of air into the corneal stroma.

The Big Bubble technique is a novel method for achieving complete separation of descemet's membrane from posterior stroma in DALK surgery.

SURGICAL TECHNIQUES OF DALK

1. Direct Open Dissection

Anwar in 1974 first described the technique of open lamellar dissection.[29] In this technique, partial trephination of corneal stroma is done upto 60-80% thickness with the trephine. Then the corneal stroma is removed in layers using a 69 beaver blade. In open lamellar dissection, the edge of the separated anterior lamellar tissue is held retracted with the help of the forceps during dissection enabling direct visualization of the area of separation.

2. Closed Dissection

After the desired depth trephination, a stromal pocket is made with the help of a Paufique knife at the incision site. The intrastromal dissection is carried out with the help of a Desmarre's lamellar dissector/ crescent knife. The lamellar corneal dissector is introduced through the pocket while lifting up the anterior lip of the flap with a Pierse Hoskin's forceps and the dissection is continued by gentle side to side movement. The lamellar dissector is held parallel to the posterior stromal bed in order to prevent perforation. The surgical field is kept dry to facilitate dissection and detect any inadvertent perforation. The method of closed lamellar dissection provides a smoother separation but is more difficult as direct visualization is not possible. In 1999, a

closed dissection technique was described by Melles et al where air is injected into the anterior chamber after paracentesis.[37]

3. **Dissection with Intrastromal Air Injection**

Archila in 1985 described this technique of intrastromal air injection. In this technique air is injected using a 26-gauge needle into the corneal stroma, which makes it opaque. Using a spatula the wound is deepened further and dissection of the stroma upto the descemet's membrane done. Then a full thickness donor button is secured in the recipient bed with interrupted sutures. Air in the corneal stroma provides a good contrast for dissection of stroma but still exposure of the DM is a problem.

4. **Dissection with Hydrodelamination**

Saline solution may also be injected into the stromal pocket to help obtain lamellar dissection with this process being termed hydrodelamination as described by Sugita et al.[35] After partial trephination of the cornea, a 27 gauge needle attached to a syringe is inserted at the bottom of the stroma and saline is injected. Now the residual stroma swells up and dissection is carried out till DM is reached. It remains to be noted that besides being a more technically demanding procedure, the rate of perforation is also high even with experienced surgeons.

5. Dissection with Viscoelastics

Viscoelastic material is injected slowly into the stromal pocket which allows the separation of the descemet's membrane from the rest of the posterior stroma as described by Manche et al.[65] The cannula is slowly advanced into the created space with continued viscoelastic injection till the complete lamellar visco-seperation is achieved.

6. Dissection with Anwar's Big Bubble Technique

In recent times the most widely practiced approach to achieve deep lamellar separation is by deep stromal air injection as described by Anwar and Teichmann in 2002.[40] The big bubble technique involves an air filled syringe attached to a 27 or 30 gauge needle and the needle is inserted into the corneal stroma with the bevel down until it approaches posterior stromal and descemet's membrane interface.

Air injection then causes rapid separation of the descemet's membrane forming a circular air pocket that is seen as a silvery bubble with a clearly defined circular edge. With the Alcon knife, the big bubble is pierced in the center and with the blade parallel to the surface further dissection is carried on. Persistent air injections further widen the separation baring the DM up to the trephination edge. Perforation rates with this technique are lower (9%). This

has been further modified by performing a manual lamellar dissection of the anterior stroma up to the depth of 50 to 60 percent stromal thickness before advancement of the needle into the deep posterior stroma for air injection. This allows for better depth perception, thereby reducing the risk of perforation. Several modification of the big bubble technique have been described.[66-68]

7. Big Bubble Technique Combined with Zigzag Femtosecond Laser Incisions

Suwan et al. in 2006[69] was the first to describe the use of femtosecond laser for anterior lamellar keratoplasty, latter by Price et al.[70] and Farid in 2009.[71] The use of femtosecond laser reduces the amount of postoperative astigmatism and provide high quality interface, thus provides better visual outcome.

COMPLICATIONS OF DALK

The complications of lamellar keratoplasty can be divided into intraoperative and post operative.

INTRAOPERATIVE:

a. **Perforation of the descemet's membrane:**

   It can happen during trephination or keratectomy or deep lamellar dissection. If it is microperforation surgery can still be carried on. And if it is big perforation it is converted into penetrating keratoplasty.

POSTOPERATIVE:

1. **Double anterior chamber:**

It happens postoperatively because of the unrecognized microperforation which would have happened during deep lamellar dissection. This double anterior chamber usually resolves in 1 to 2 weeks. If it doesn't then we have to take the patient again to the operating room and drain the aqueous from both the anterior chamber and the supernumerary chamber.

2. **Delayed epithelisation:**

Prolonged surgery with exposure and drying of the ocular surface is responsible for delayed epithelisation of the graft. This may also result due to damage to the limbal stem cells. Frequent preservative free lubricants will help to re-epithelise early. If required bandage contact lens or tarsorrhaphy may be done.

3. **Stromal melting:**

Persistent epithelial defect can lead to sterile corneal stromal melting or sometimes superadded infection can also give rise to corneal melt.

4. **Microbial keratitis:**

Infection can also be one of the postoperative complication after lamellar keratoplasty. Prompt diagnosis and management is required in such cases.

5. **Astigmatism:**

Irregular astigmatism can many times be a reason for non improvement of the vision. Several reports have suggested that the astigmatism following lamellar keratoplasty is generally less than compared to the penetrating keratoplasty.

6. **Interface Scarring:**

It is probably because of the irregular and rough stromal bed dissection. When dissection has reached the descemet's membrane, there will be no interface scarring.

7. **Graft Rejection:**

Acute stromal rejection has been reported following lamellar keratoplasty which responds favourably to increased dosage of steroids.

The advantages of DALK are :

- Anterior lamellar keratoplasty retains the normal receipient endothelial layer, thereby reducing the risk of endothelial graft rejection.[62]
- DALK is largely a non-penetrating surgery, it reduces the risk of intraocular complications such as positive pressure, iris prolapse, glaucoma, cataract, choroidal effusion/hemorrhage, retinal detachment, and endophthalmitis.[72]
- DALK does not require good endothelial quality donor tissue. There is minimal detrimental effect on endothelial cell count.
- As the descemet's membrane is not disturbed, DALK technically achieves a stronger corneal wound. Traumatic rupture of PKP graft can happen months

to years after the surgery.[73] There are clinical reports suggesting that traumatic dehiscence of DALK wounds would be less severe than that would have occurred in PKP eyes.[74]

- Sutures can be removed earlier with DALK, and suture related astigmatism is lesser in DALK procedures.

The disadvantages of DALK are as follows:

- DALK cannot be done in corneal conditions involving the endothelium. In disease with scarring down to the level of descemet's membrane or post acute hydrops in keratoconus , penetrating keratoplasty found to be useful.
- Suboptimal visual acuity compared to PKP due to interface problems, lamellar dissection irregularity and residual scarring.
- DALK is technically more demanding and time consuming and requires longer learning curve.

Thus many studies were conducted comparing the outcomes of penetrating keratoplasty and deep anterior lamellar keratoplasty for keratoconus. We took up the study to compare the newer technique of keratoplasty, DALK, over the gold standard procedure PKP and analyze the visual outcomes of both the procedures.

REVIEW OF LITERATURE

1. Deep anterior lamellar keratoplasty versus penetrating keratoplasty for keratoconus: A clinical trial:

Mohammad Ali Javadi, Sepehr Feizi, Shahin Yazdani, Firooz Mirbabaee
Cornea 2010; 29:365-371

Mohammad Ali Javadi et al. ,performed a randomized comparative trial in which patients were randomly assigned to DALK or PKP at the time of planning. Of the 81 eyes enrolled into the trial; 46 eyes underwent DALK from which 4 were excluded because of failure to achieve bared descemet membrane and 35 patients underwent PKP. Final mean BCVA was 0.18± 0.08 logMAR in the DALK group versus 0.15 ± 0.10 logMAR in the PKP group. Mean postoperative spherical equivalent refractive error was -2.91 ± 1.7 D and -2.31 + 2.3 D in the DALK nad PKP group respectively. In this study photopic and scotopic contrast sensitivity function (CSF) and higher order aberrations (HOA) were comparable in the 2 groups. The rate of graft rejection in the PKP group was 42.9% and 23.8% for DALK group. In conclusion, the outcomes of DALK for keratoconus are comparable to PKP in terms of refractive error , keratometric astigmatism, BCVA, CSF and HOAs.

2. Comparison of deep lamellar keratoplasty and penetrating keratoplasty in patients with keratoconus.

   Watson SL, Ramsay A, Dart JKG, Bunce C, Craig E. Ophthalmology.2004; 111(9): 1676-82.

Watson et al. compared the outcomes of 26 eyes which underwent deep lamellar keratoplasty with 25 eyes with PKP in patients with keratoconus. They used the Melles technique in 7 eyes and technique described by Sugita and Kondo in 19 eyes for DALK. The median follow up time for patients in the DALK group was 28 months whereas it was 55 months in the PKP group. Median final BCVA was 6/9 in the DALK and 6/6 in the PKP group, thus the median visual acuity is slightly better for patients following PKP than DALK . The median astigmatism was also less than 5 D cylinders in both the groups. Complication rates were also similar in the two groups. They concluded that DALK is a safer alternative to PKP in keratoconus with similar results although DALK is a technically challenging procedure.

3. Comparative cohort study of the outcomes of deep lamellar keratoplasty and penetrating keratoplasty for keratoconus.

   Funnell CL, Ball J, Noble B A. Eye (London, England). 2006 May; 20(5):527-32.

Funnell et al compared the visual outcomes and the complications associated with PKP versus DALK in 20 keratoconus patients in each group. Patients were followed up for 1 year in each group. They used Melles technique of DALK. There was no significant difference in the patients achieving 6/9 in each group but 70% patients in PKP group compared to only 22%patients in DALK group achieved 6/6 at the end of 1 year. Astigmatism was found to be significantly high in PKP group. 2 episodes of graft rejection was seen in PKP group compared to none in DALK group. Finally they concluded that DALK has the advantage of no endothelial graft rejection over PKP and the visual outcome is similar except that achieving VA of 6/6 is lesser in DALK group.

4. Comparison of outcomes of lamellar keratoplasty and penetrating keratoplasty in keratoconus.

   Han DCY, Mehta JS, Por YM, Htoon HM, Tan DTH. American journal of ophthalmology.2009; 148(5):744-751.

Han et al compares the outcome between PKP done in 100 eyes and DALK done in 14 eyes by Anwar's big bubble technique(DALKa) and 11 eyes by manual technique (DALKm). At the end of 1 year there was no significant difference in BSVA between PKP and DALKa group. Although BSVA outcome between DALKa and DALKm group was significant. The DALK group together was associated with fewer incidences of complications compared to PKP. Graft survival for both PKP and DALKa was 100% whereas for DALKm it was 73%. They further suggested the need of a study for long term analysis of these results.

Penetrating keratoplasty has long been considered the gold standard treatment for keratoconus. But due to significant complications following PKP and the higher risk of endothelial graft rejection, lamellar keratoplasty is replacing PKP as the procedure of choice. Deep anterior lamellar keratoplasty has the advantage of reduced risk of graft rejection since patient's endothelium

is retained and theoretically has decreased postoperative complications, since it is an extraocular procedure. But the visual outcome following DALK may be lower than PKP due to interface haze and residual stromal bed. With the advent of newer techniques of DALK comparable visual outcomes with PKP have been reported in many studies. In our study, we compare the visual outcome following PKP and DALK in keratoconus patients.

5. Corneal transplant surgery for kerataconus and the effect of surgeon experience on deep anterior lamellar keratoplasty outcomes.

Kasbekar S, Jones MNA, Ahmad S,Laskin DFP, Kaye SB. American journal of ophthalmology. (Accepted for Publication) 2014.08.029

A Multicentre cohort study which included 4521 patients of which 3297 patients had undergone PKP and 1224 patients had undergone DALK between April 1999 and March 2010 in United kingdom. The study showed no significant difference in the overall five year graft survival between DALK and PKP. The presence of ocular surface disease was significantly associated with an increased risk of graft failure following DALK. There was no significant difference in mean BCVA at 5 yrs for all surviving grafts. But greater proportion of patients achieved 6/6 Snellen visual acuity following PKP

compared to DALK, but there were no differences in the proportion of patients with a BCVA of 6/60 or worse. Patients who had undergone DALK had a slightly more myopic refractive error. The study also showed that there was no significant difference in the mean refractive error versus surgeon experience.

AIM AND OBJECTIVES

AIM:

To compare the visual outcomes of penetrating keratoplasty and Deep anterior lamellar keratoplasty procedures in keratoconus.

OBJECTIVES:

1. To analyze the visual and refractive outcomes after penetrating keratoplasty and deep anterior lamellar keratoplasty procedures in keratoconus.
2. To analyze the intra-operative and post-operative complications after penetrating keratoplasty and deep anterior lamellar keratoplasty in keratoconus.

OUTCOME MEASURES:

Primary outcome measure:

1. Mean BCVA at the final follow up of 6 months after penetrating keratoplasty and deep anterior lamellar keartoplasty.
2. Mean refractive and keratometric astigmatism at the final follow up of 6 months after penetrating keratoplasty and deep anterior lamellar keratoplasty.

Secondary outcome measure

Rate of post-operative complications associated with penetrating keratoplasty and deep anterior lamellar keratoplasty.

MATERIALS AND METHODS

Design:

This is a hospital based prospective, non randomized study conducted at Aravind Eye hospital, Madurai.

Duration of study:

Patients were recruited from April 2013 to March 2014 and were followed up for a minimum 6 months .

INCLUSION CRITERIA:

Moderate (46D-less than 55D) to severe (>55 D) keratoconus with

1. Poor spectacle corrected visual acuity
2. Intolerance to Rigid gas permeable contact lens
3. Inappropriate contact lens fit.

EXCLUSION CRITERIA:

1. Coexistence of other corneal pathologies (hydrops, stromal opacification, Descemet tear, cataract, retinal disorder, glaucoma)
2. Patient not willing for the study, and those who did not adhere to the recommended follow up.

DIAGNOSIS:

Diagnosis of the disease was based on

1. careful history,
2. slit lamp examination showing signs of keratoconus like corneal ectasia, stromal thinning, Fleischer ring, vogt striae
3. Manual keratometry values and confirmed by corneal topography.

INFORMED CONSENT

An informed consent was taken from every patient after explaining the procedure and the outcome of the surgery in detail including the possibility of the various complications in his or her own language. Patients were informed about the frequent follow-ups involved in the study. For minors, consent was taken from the parents of the minor. Consent for participating in the study was also taken and adhered to the tenets of the Helsinki declaration.

SURGICAL TECHNIQUE

Penetrating keratoplasty and deep anterior lamellar keratoplasty were performed by surgeons having experience in lamellar and full thickness graft surgery. Procedure was performed under general or local anaesthesia depending upon the age of the patients. The choice of the surgery was decided depending on the extent of the corneal disease and surgeon's preference. DALK was done by free hand lamellar dissection technique or by big bubble technique depending upon the surgeon's preference.

SURGICAL TECHNIQUE OF DALK- FREE HAND LAMELLAR CORNEAL STROMAL DISSECTION:

1. Local anaesthesia either retrobulbar or peribulbar block was used. In case of younger patient general anaesthesia was given.
2. Wire speculum was applied to open the eyelids and expose the globe.
3. Superior rectus bridle suture was secured so that the eye can be moved as desired.
4. Partial trephination of the host cornea to an approximate depth of 60-70 percent of the minimum corneal thickness was done.
5. Paracentesis wound was created with a 15 degree surgical blade, just posterior to the limbus.

6. Then manual dissection was started from the edge of the trephine with the help of the crescent blade and the forceps.
7. When the desired stromal depth was reached, the crescent was positioned parallel to the posterior corneal surface, and dissection of the stroma was made across the cornea.
8. Then the recipient bed was thoroughly irrigated and smoothened.
9. After removal of the stromal tissues, the donor button was transferred to the recipient stromal bed and secured with 10'0 nylon sutures in an interrupted fashion.

SURGICAL TECHNIQUE OF ANWAR'S BIG BUBBLE FOR DALK:

1. Local anaesthesia either retrobulbar or peribulbar block was used. In case of younger patient general anaesthesia was given.
2. Wire speculum was applied to open the eyelids and expose the globe.
3. Superior rectus bridle suture was secured so that the eye can be moved as desired.
4. Partial trephination of the host cornea to an approximate depth of 60-70 percent of the minimum corneal thickness was done.
5. 27 G needle bend around 60 degree of an arc at the base of the needle and connected to an air filled syringe.

6. The needle with its bevel facing down was then advanced into the corneal stroma at about 80 percent depth through the trephination groove parallel to the posterior corneal surface.
7. When the tip of the needle had reached 3-4 mm into the corneal stroma, the plunger was depressed and the air was injected.
8. A circular white band with its margins correlating with the trephination groove was noted which confirms that the big bubble was achieved.
9. Overlying the air bubble, a small incision was then created in the stromal tissue and then the air bubble was allowed to egress from the incision site. Viscoelastic was injected into the plane between the stroma and the descemet's membrane.
10. The stromal tissue was divided into four quadrants with the use of a curved vannas scissors, and each quadrant was excised baring the descemet's membrane.
11. After removal of the stromal tissues, the donor button was transferred to the recipient stromal bed and sutured with 10'0 nylon sutures in an interrupted fashion.

SURGICALTECHNIQUE OF PENETRATING KERATOPLASTY

1. Local anaesthesia either retrobulbar or peribulbar block was used. In case of younger patients general anaesthesia was given.

2. Wire speculum was applied to open the eyelids and expose the globe.

3. Superior rectus bridle suture was secured so that the eye can be moved as desired.

4. Partial trephination of the host cornea to an approximate depth of 80 percent of the corneal thickness was done.

5. The Anterior chamber was then entered with a 15 number blade. Pilocarpine was injected to constrict the pupil and viscoelastic was injected to form the anterior chamber.

6. The host cornea was excised with the corneal scissors and the edges were trimmed and smoothened with vannas scissors.

7. Peripheral iridectomy was then made in 10’clock or 2’0 clock quadrant to control the postoperative increase in intraocular pressure.

8. The full thickness corneal graft was placed and secured with 10’0 nylon sutures in an interrupted fashion and the anterior chamber was formed with saline.

POSTOPERATIVE MANAGEMENT AND FOLLOW UP

Medication:

Corticosteroids:

Topical 1 percent prednisolone acetate four times a day was used post surgically. According to the patient's response the steroid dose was tapered.

Antibiotics:

Topical broad spectrum antibiotics like gatifloxacin or moxifloxacin were used four times a day for three to six months.

Lubricants:

Preservative free lubrication was used for atleast a month following keratoplasty. It aides in the re-epithelization.

Suture Removal:

Sutures were removed if it was infected or loosened or broken or causing vascularisation. It was also indicated when it was causing high or irregular astigmatism.

Follow up:

Patients were admitted for atleast three to five days after the procedure when the epithelisation was occurring and the corneal edema was settling down.

Thereafter patient was reviewed after a month, again at 3 months and then at 6 months post-operatively. Every visit careful slitlamp examination and refraction was done.

PREOPERATIVE AND POSTOPERATIVE OCULAR EXAMINATION

The following examination was done before and after surgery:

- Uncorrected visual acuity(UCVA)
- Best corrected visual acuity(BCVA)
- Slit lamp examination
- Tonometry (noncontact tonometer)
- Fundus examination
- Manifest refraction
- Corneal topography

The comprehensive ophthalmic examination was done for every patients at each visits and were recorded on a preset proforma along with the mention of the complication and the additional intervention if any.

BEST CORRECTED VISUAL ACUITY

- Visual acuity was tested by using snellen's chart at 6 meters.
- Refraction was done at all visit except in cases of acute pain and redness.

SLIT LAMP EXAMINATION

- Donor graft and the recipient cornea were examined carefully for any abnormalities like graft edema, interface haze etc.
- Sutures were carefully examined to see the tightness or if associated with vascularisation.
- Graft host junction was checked for any dehiscence or overriding.
- Conjunctiva, anterior chamber depth and inflammatory reaction, iris changes, pupil, lens status etc. were noted at each visit.

FUNDUS EXAMINATION

Dilated fundus examination was done in each case wherever possible with +90 Diopter lens using slit lamp biomicroscopy. The cup-disc ratio was recorded in each case and any asymmetry of cup-disc ratio, neuroretinal rim thinning were noted.

TOPOGRAPHY

Corneal topography was done preoperatively for all keratoconus patients and was repeated post operatively at 6 months. Steepness of the cornea along with topographic astigmatism was analyzed. If the orbscan fails to capture the

image then manual keratometry readings were taken to determine the astigmatism.

POSTOPERATIVE FOLLOW UP

Patients were discharged after 3 to 5 postoperative days

Patients were followed up for a minimum period of 6 months

1st follow up at 1 month.

2nd follow up at 3 months.

3rd follow up at 6 months.

MAIN OUTCOME MEASURES

Post operative uncorrected visual acuity (UCVA)

Post operative best corrected visual acuity (BCVA)

Manifest refraction

Corneal topography

Intra operative and post operative complications.

DATA COLLECTION TECHNIQUE AND TOOLS

All the data from the primary source was collected by an individual interview, observation, and complete ophthalmic examination of the subjects as per the present proforma and any additional information like a complication and its management was mentioned in detail. Later these primary data were entered in to a Microsoft excel sheet for a complete database. Data was also collected from secondary sources like pubmed, medline and various journals for comparision with the primary data.

STATISTICAL METHODS

Mean (SD) and Frequency (percentage) was used for continuous and categorical variables respectively. Fisher's exact test or chi-square test was used to assess the difference between the categorical variable. Student t-test or Mann-whitney U test was used to test mean difference between the two continuous variables. P-value of less than 0.05 considered as statistically significant. All statistical analysis was done by statistical software STATA 11.0.

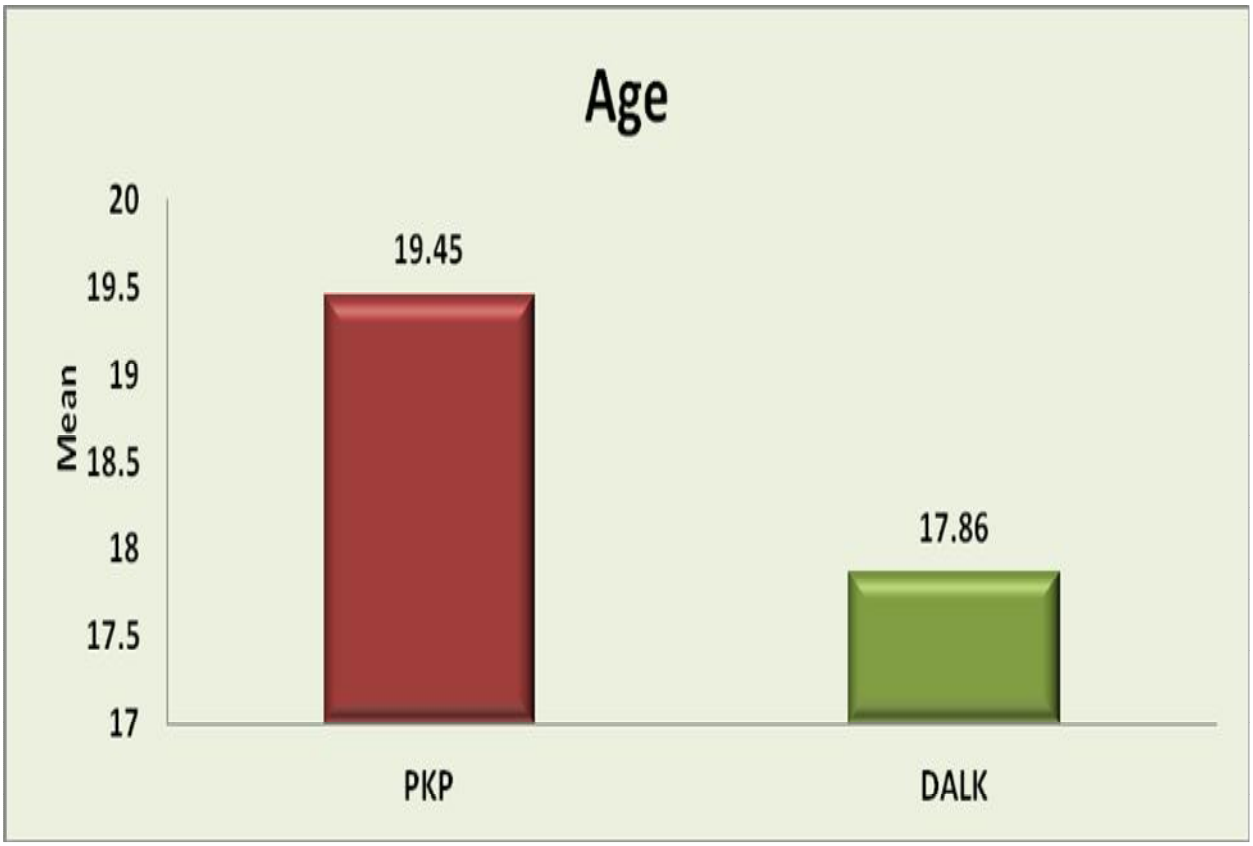
OBSERVATION AND RESULTS

A total of 26 eyes of 26 patients were included in the study as per study protocol to analyze the outcomes of penetrating keratoplasty and deep anterior lamellar keratoplasty. Of these, 15 patients underwent DALK and 11 patients underwent penetrating keratoplasty. This is a prospective study done at the department of cornea of Aravind eye hospital, Madurai. Demographic profile of the patients included in the study is summarized below.

AGE DISTRIBUTION:

Mean age of the patients who underwent PKP in the study was 19.45 years with the age range of 13 years to 31years. Mean age of patients who underwent DALK in the study was 17.86 years with the age range from 10 years to 30 years. The age distribution in both groups was similar and statistically no significant difference (p value of 0.473)

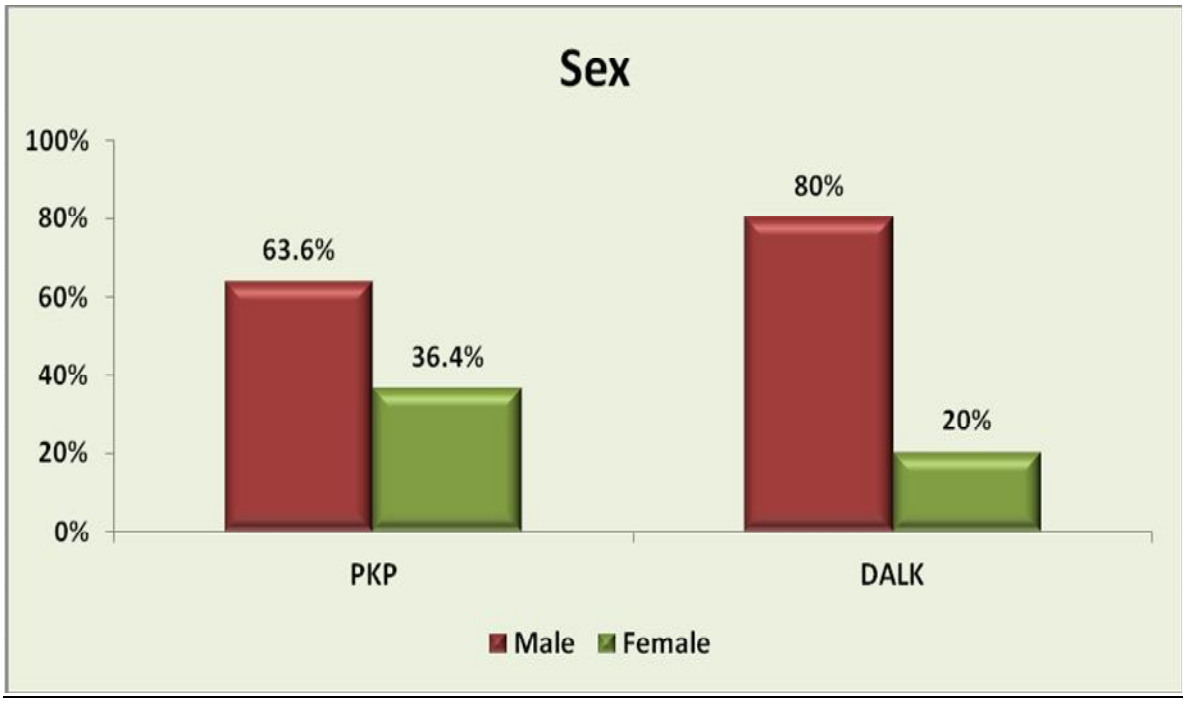
Variable	Group		Total (n=26)	P-value
	PKP (n=11)	*DALK (n=15)*		
Age(years)				
Mean(SD)	19.45(5.32)	17.86(5.53)	18.56(5.39)	0.473
Range	13 – 31	10 – 30	10 – 31	



GENDER DISTRIBUTION:

Variable	Group		Total (n=26)	P-value
	PKP (n=11)	***DALK (n=15)***		
Sex				
Male	7(63.6)	12(80.0)	19(73.1)	0.407
Female	4(36.4)	3(20.0)	7(26.9)	

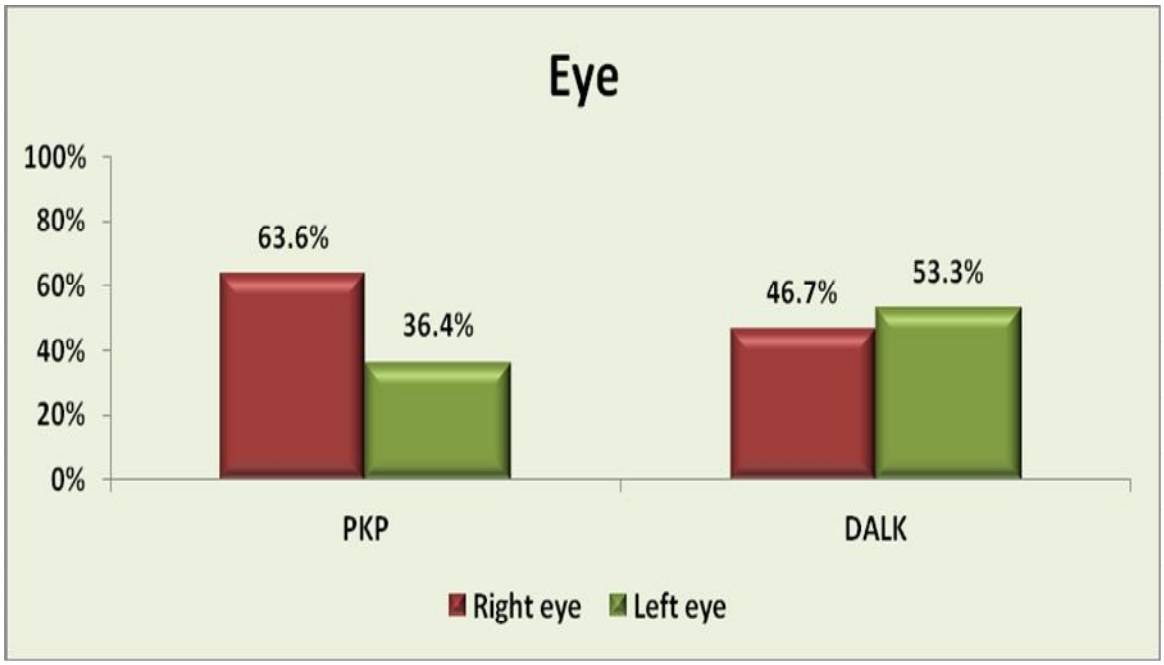
Out of the 26 patients, 19 were male and 7 were female. In the PKP group, 7 were male and 4 were female, and in DALK group 12 were male and 3 were female. A male preponderance was noted in both the groups.



EYE:

PKP was done in 7 patients in the right eye and 4 patients in the left eye and DALK was done in 7 patients in the right eye and 8 patients in the left eye.

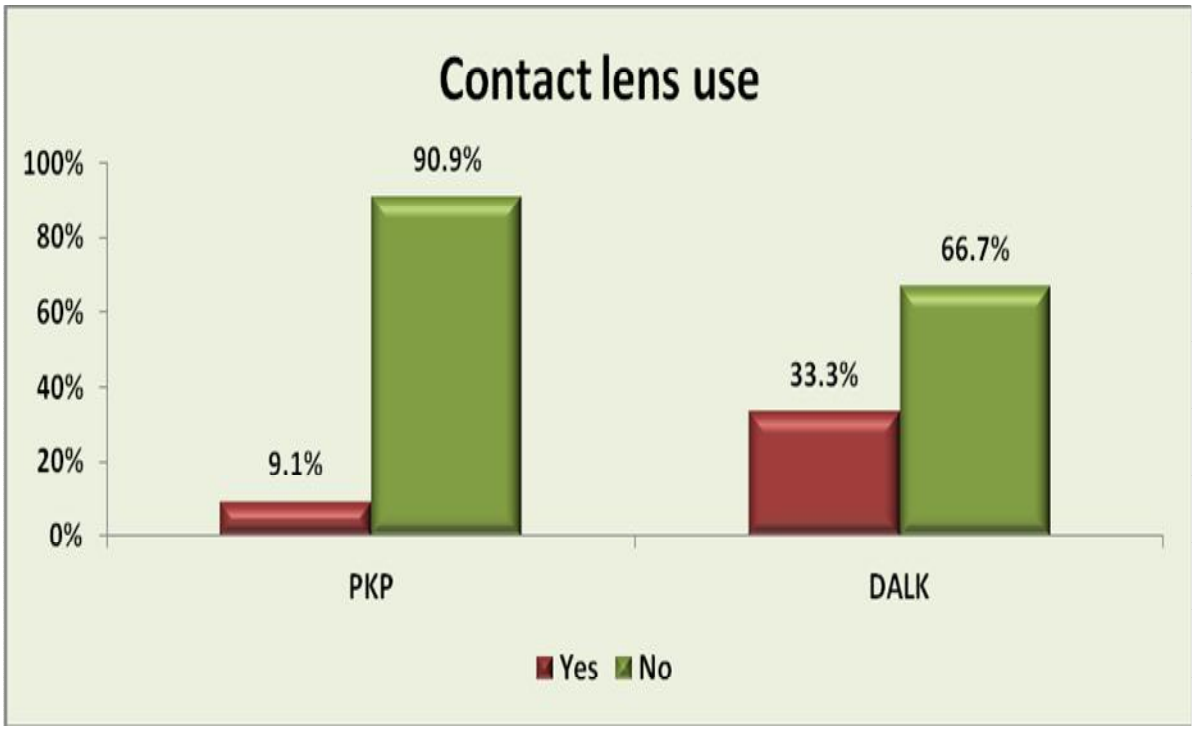
Variable	Group		Total (n=26)
Eye	***PKP (n=11)***	***DALK (n=15)***	
Right	7(63.6)	7(46.7)	14(53.9)
Left	4(36.4)	8(53.3)	12(46.1)



CONTACT LENS USE:

Pre operatively rigid gas permeable contact lens use had been presuited for 1 patient in PKP group and 5 patients in DALK group.

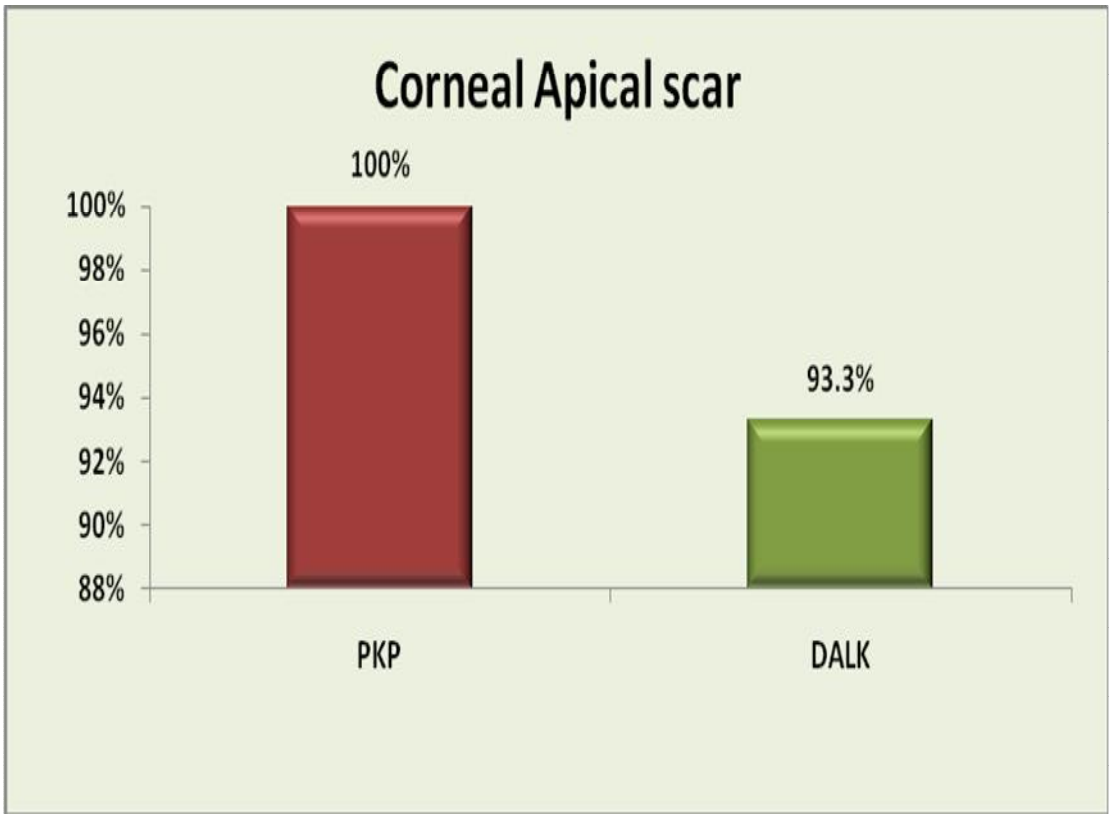
Variable	Group		Total (n=26)
Contact lens use	***PKP (n=11)***	***DALK (n=15)***	
Yes	1(9.1)	5(33.3)	6(23.1)
No	10(90.9)	10(66.7)	20(76.9)



CORNEAL APICAL SCAR:

Preoperatively corneal apical scar was seen in almost all cases, all of 11 patients who underwent PKP, and 14 of the patients who underwent DALK had corneal scar.

Variable	**Group**		**Total (n=26)**
Corneal Apical scar	***PKP (n=11)***	***DALK (n=15)***	
Yes	11(100.0)	14(93.3)	25(96.2)
No	-	1(6.7)	1(3.8)



GRAFT SIZE DISPARITY :

Variable	Group		Total (n=26)
Graft size disparity	***PKP (n=11)***	***DALK (n=15)***	
0.2mm	8(72.7)	15(100.0)	23(88.5)
0.5mm	3(27.3)	-	3(11.5)

A 0.2mm larger graft was used in all patients in DALK group and 8 patients in PKP group. For 3 patients in PKP group, there were a graft disparity of 0.5mm.

SPHERICAL EQUIVALENT (SE):

In few patients mean spherical equivalent could not be found either because the visual acuity was not improving or refraction was not done in view of the patients discomfort associated with coexistent complication. Preoperatively SE was calculated for 3 patients in PKP group and 7 patients in DALK group, for others vision was not improving due to corneal scarring. Postoperatively at 6 months, SE was calculated for 8 patients in PKP group and 6 patients in DALK group, one patient in PKP group had infiltrate in the graft and SE could not be calculated, for others vision was not improving on refraction.

Spherical equivalent	PKP		DALK		P-value
	Mean(SD)	Min – Max	Mean(SD)	Min – Max	
Baseline	-7.25(1.75)	-9.25 to -6.0	-16.32(2.95)	-20.25 to -11.25	0.016
6months	-0.53(2.11)	-3.00 to 2.75	0.00(3.05)	-5.5 to 3.5	0.399

REFRACTIVE ASTIGMATISM:

Mean refractive astigmatism preoperatively in PKP group was -3.83D, which changed to -0.88D, -1.70D and -1.31D at 1 month,3 months and 6 months postoperatively respectively. The mean refractive astigmatism preoperatively in DALK group was -3.5D which changed to 0.40D, 0.86D, 0.33D at 1 month, 3 month, and 6 months postoperatively respectively.

Refractive astigmatism	PKP		DALK	
	Mean(SD)	Min – Max	Mean(SD)	Min – Max
Baseline	-3.83(1.26)	-5 - -2.5	-3.5(0.94)	-4.5 - -2.5
1month	-0.88(3.79)	-4 – 4.5	0.40(3.65)	-4 – 4
3month	-1.70(3.83)	-6 – 5	0.86(3.52)	-4 – 6
6month	-1.31(4.11)	-6 – 5.5	0.33(2.25)	-3 – 2

KERATOMETRIC ASTIGMATISM:

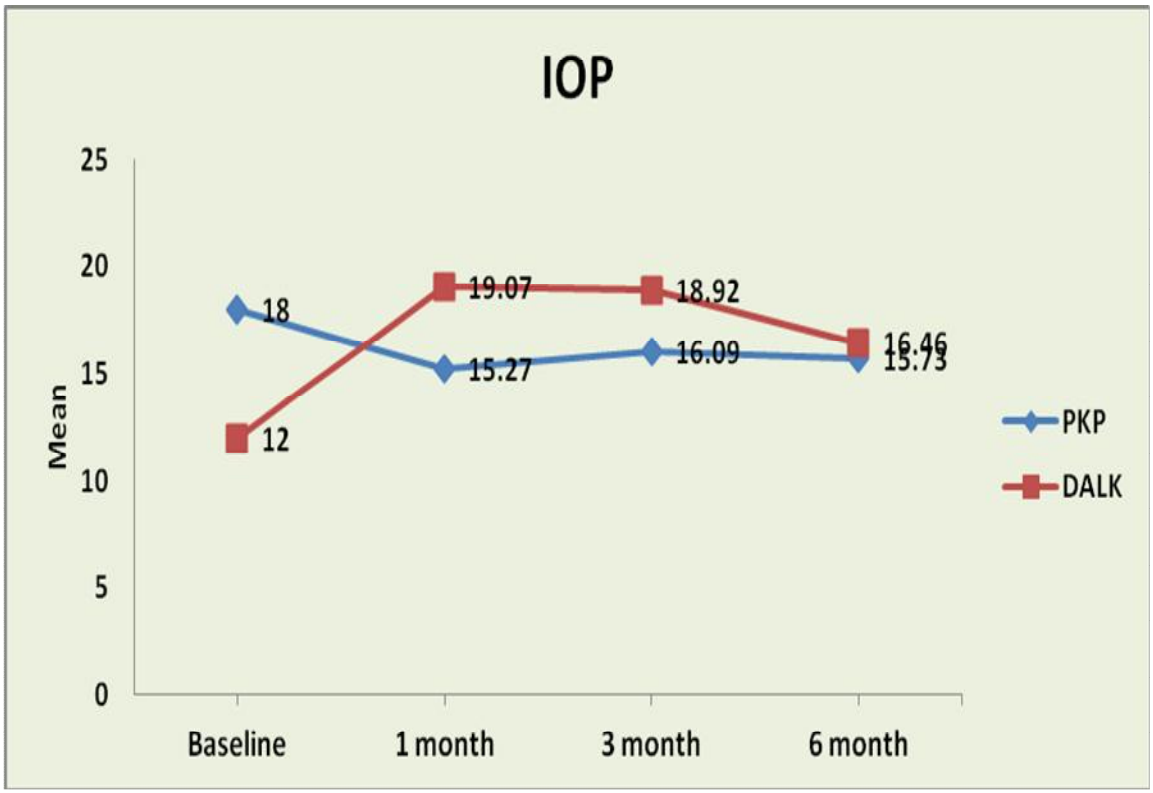
The mean keratometric astigmatism at 6 months postoperatively was 7.78± 4.43D and 9.42 ±6.27D in PKP and DALK respectively. There was no statistical difference between two groups with p value of 0.642.

Keratometry Astigmatism 6months	Mean(SD)	Min – Max	P-value
PKP	7.78(4.43)	3.5 – 19.75	0.642
DALK	9.42(6.27)	1.5 – 21	

INTRAOCULAR PRESSURE:

IOP was measured by non contact tonometer both preoperatively and postoperatively. Preoperatively IOP could not be measured for around 17 patients due to corneal scarring and protrusion. Postoperatively IOP raise was noted in a few cases. IOP was increased for 4 patients in DALK group and 2 patients in PKP group postoperatively. In all these cases rise in IOP was transient and treated with antiglaucoma medications for a short period. No patients required glaucoma surgery to control IOP. The mean IOP for PKP group at baseline was 18 mm of Hg and 15.73mm of Hg at 6 months. In DALK group the mean baseline IOP was 12 mm of Hg and 16.46 mm of Hg at 6 months postoperatively.

IOP	**PKP**		**DALK**	
	Mean(SD)	**Min – Max**	**Mean(SD)**	**Min – Max**
Baseline	18.00(2.83)	16 – 20	12.00(3.00)	8 – 16
1month	15.27(3.10)	11 – 20	19.07(5.99)	9 – 36
3month	16.09(3.70)	11 – 23	18.92(8.08)	9 – 40
6month	15.73(4.20)	10 – 24	16.46(4.22)	10 – 28



VISUAL ACUITY:

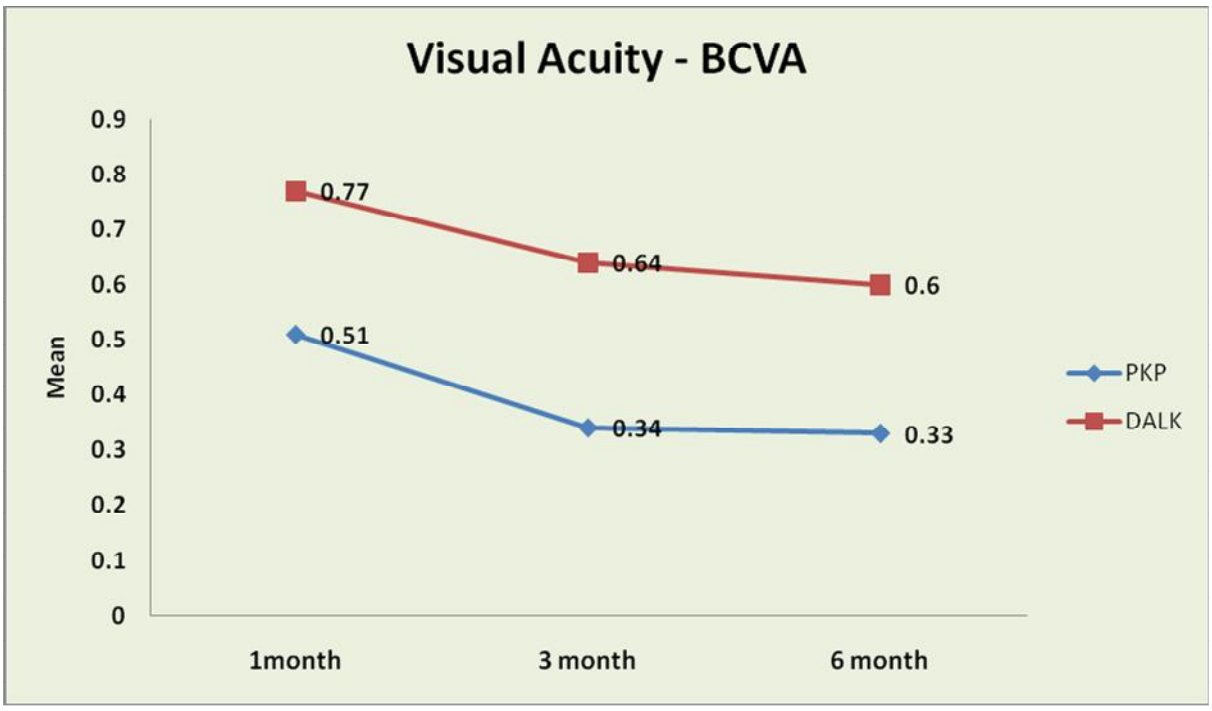
Visual acuity was recorded by snellen's chart for all the patients on all visits. For the ease of comparision visual acuity was converted to logMAR snellen VA.

The mean Snellen logMAR BCVA for PKP group was 1.13± 0.32, 0.51 ± 0.21, 0.34 ± 0.13 and 0.33 ±0.14 at baseline, 1 month, 3 months and 6 months respectively.

The mean Snellen logMAR BCVA for DALK group was 1.14 ± 0.38, 0.77 ± 0.26, 0.64 ± 0.29, and 0.60 ± 0.30 at baseline, 1 month, 3 months, and 6 months respectively.

There was significant statistical difference in visual acuity between two groups at end of 1month, 3 months and 6 months (P value less than 0.05). There was better visual acuity in PKP group than DALK group at end of 6 months postoperatively which was statistically significant.

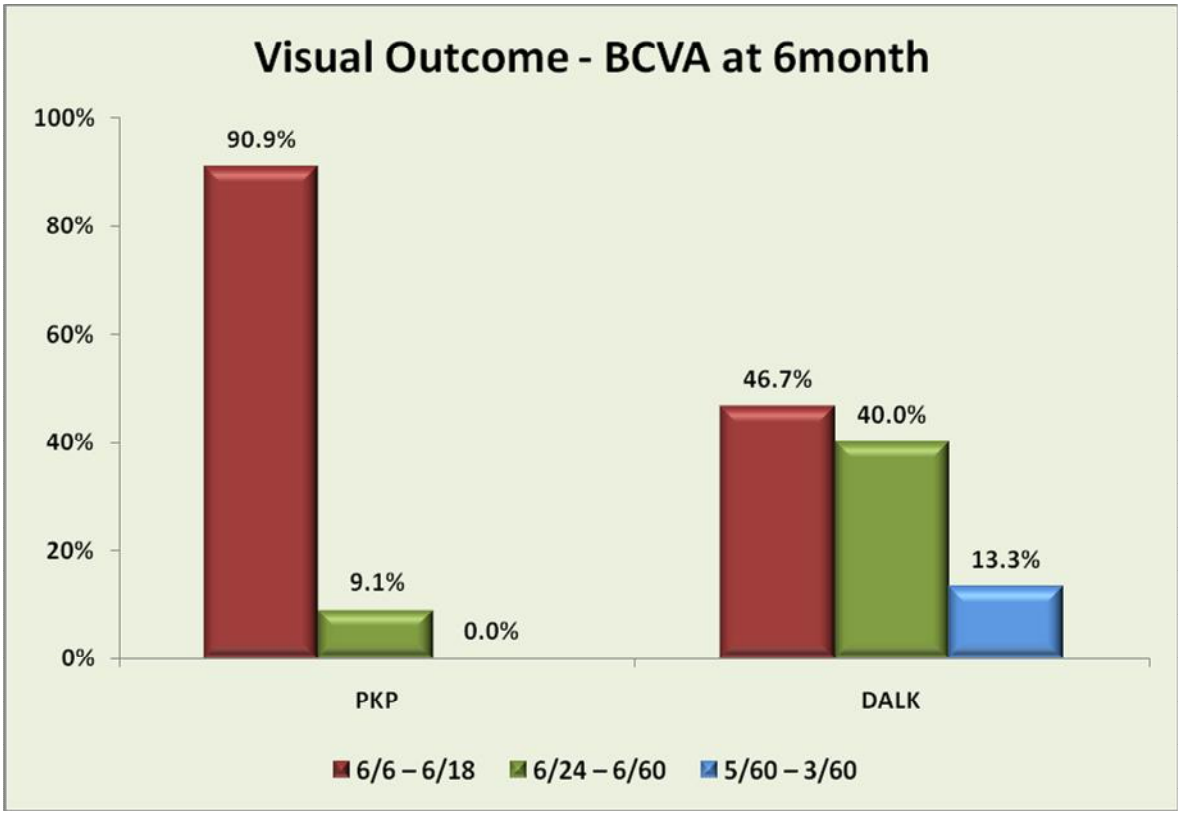
Variable	**PKP**			**DALK**			**P-value**
	Median (Snellen VA)	Mean(SD)	Min – Max	Median (Snellen VA)	Mean(SD)	Min – Max	
Baseline CL VA	0.48(6/18)	0.51(0.22)	0.3 – 0.78	0.3(6/12)	0.45(0.31)	0.18 – 1	0.352
UCVA							
Baseline	1.30(3/60)	1.35(0.43)	0.6 – 2.3	1.48(2/60)	1.45(0.32)	0.78 – 1.78	0.244
1month	0.6(6/24)	0.67(0.28)	0.18 – 1.08	1.00(6/60)	0.93(0.35)	0.3 – 1.78	0.057
3month	0.78(6/36)	0.78(0.30)	0.3 – 1.08	0.78(6/36)	0.84(0.31)	0.3 – 1.48	0.692
6month	0.78(6/36)	0.71(0.33)	0.18 – 1.08	0.78(6/36)	0.79(0.24)	0.3 – 1.08	0.633
BCVA							
Baseline	1.08(5/60)	1.13(0.32)	0.6 – 1.78	1(6/60)	1.14(0.38)	0.48 – 1.78	0.823
1month	0.48(6/18)	0.51(0.21)	0 – 0.78	0.78(6/36)	0.77(0.26)	0.3 – 1.08	0.016
3month	0.3(6/12)	0.34(0.13)	0.18 – 0.6	0.6(6/24)	0.64(0.29)	0.3 – 1.08	0.004
6month	0.3(6/12)	0.33(0.14)	0.18 – 0.6	0.6(6/24)	0.60(0.30)	0.3 – 1.08	0.012



VISUAL OUTCOME:

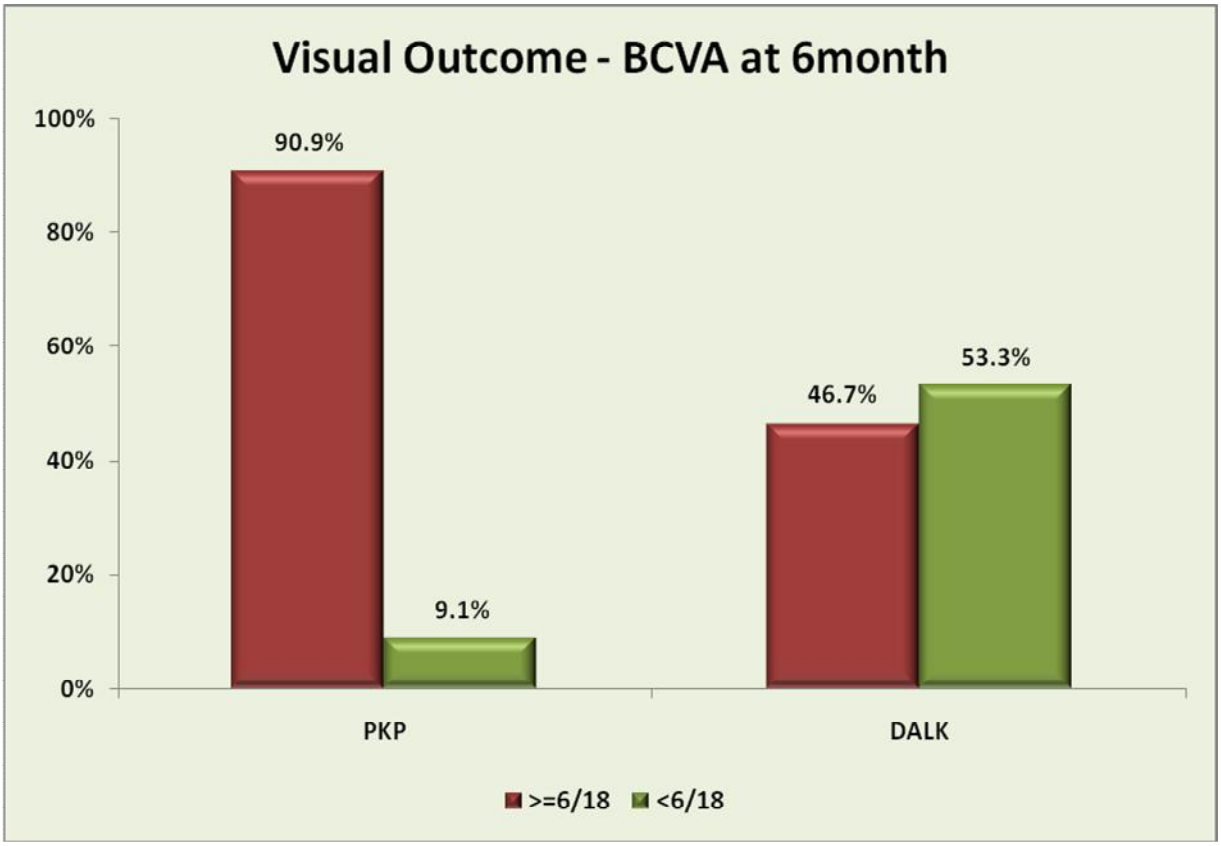
Comparing the visual outcome at the end of 6 months of two groups showed that in PKP group 10 patients out of 11 patients had BCVA of 6/6 – 6/18, while in DALK group out of 15 patients only 7 patients had BCVA of 6/6 – 6/18, 6 patients had BCVA of 6/24 – 6/60 and 2 patients had BCVA in the range of 5/60 – 3/60.

BCVA at 6months	PKP		DALK	
	n	%	N	%
6/6 – 6/18	10	90.9	7	46.7
6/24 – 6/60	1	9.1	6	40.0
5/60 – 3/60	-	-	2	13.3
<3/60	-	-	-	-
Total	11	100.0	15	100.0



Thus in PKP group 90.9% of the patients had vision improved to better than 6/18, while in DALK group only 46.7% of the patient had vision better than 6/18 at the end of 6 months, which was statistically significant (P value of 0.036).

BCVA at 6months	PKP		DALK		P-value
	N	%	n	%	
>=6/18	10	90.9	7	46.7	
<6/18	1	9.1	8	53.3	0.036
Total	11	100.0	15	100.0	



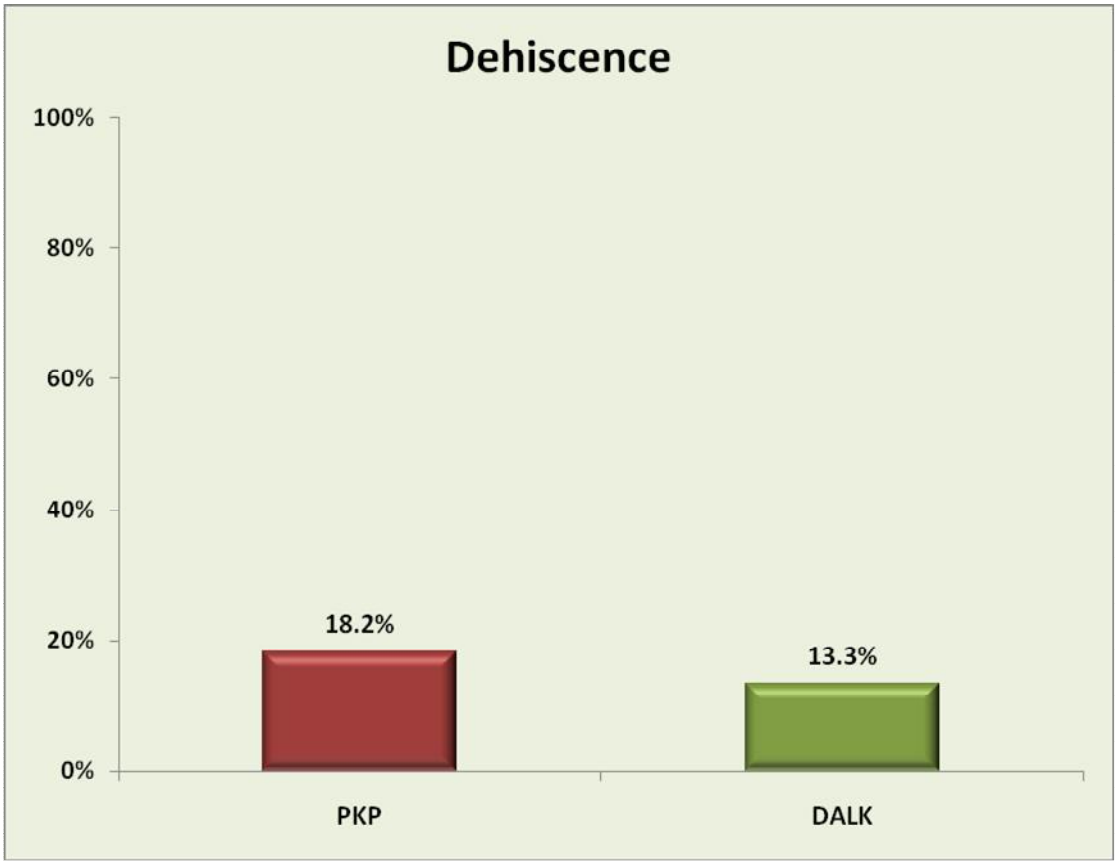
COMPLICATIONS:

There were no major intraoperative complications in any of the 26 surgeries. The major post operative complications seen in this study were graft dehiscence, and infiltrates in the graft tissue. There was no incidence of graft rejection or graft failure in the follow up period of 6 months in both PKP and DALK group.

GRAFT DEHISCENCE:

Graft dehiscence occurred in 2 patients in PKP group and 2 patients in DALK group. In PKP group, the graft dehiscence occurred following trauma in both patients at 1 and 2 months postoperatively. In DALK group, graft dehiscence occurred following trauma in one patient after 1 month of surgery, and in the other patient spontaneous partial graft dehiscence occurred at 3 months postoperatively. All of these patients underwent graft resuturing and regained graft stability. On follow up of these patients, the graft was stable in position with better visual acuity.

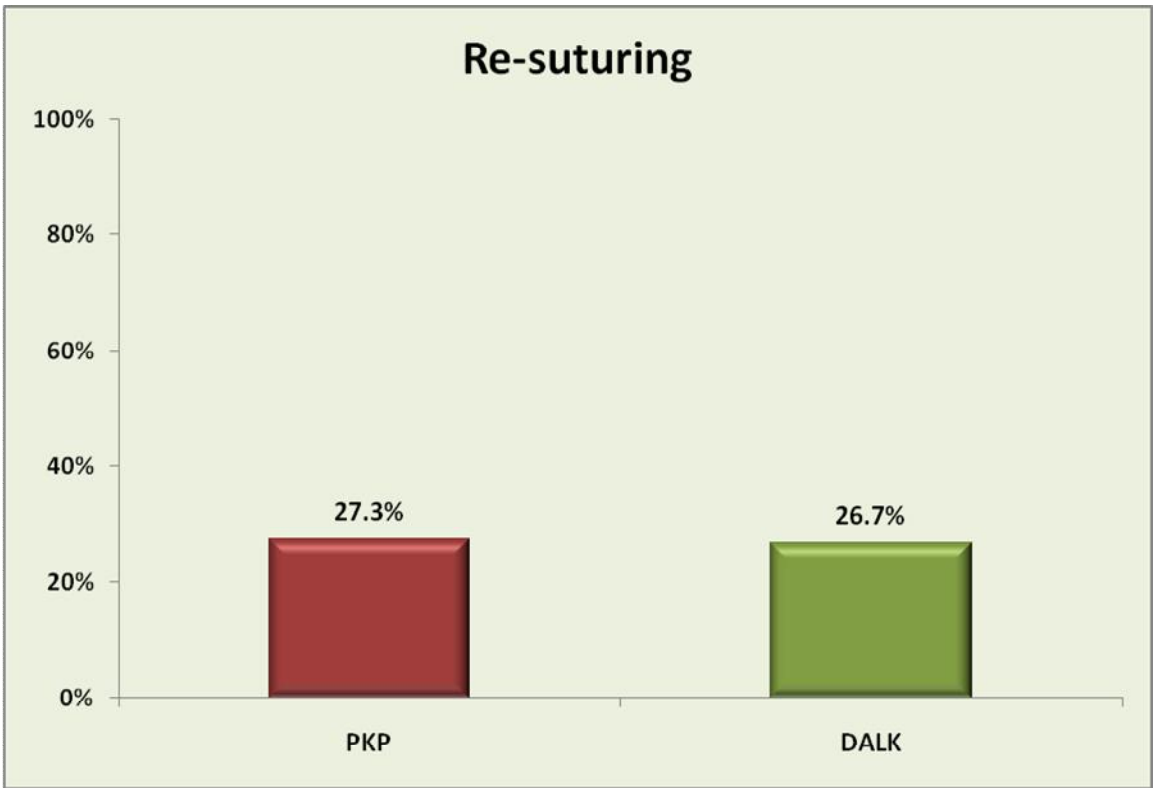
Post-op complications	PKP		DALK	
	n	%	n	%
Dehiscence				
Yes	2	18.2	2	13.3
No	9	81.8	13	86.7



RESUTURING:

Resuturing of the graft was done when there was threat to the stability of the graft like in graft dehiscence, multiple loose sutures with unstable graft host junction. In PKP group resuturing was done in 3 out of 11 patients, one patient in the immediate postoperative period due to broken sutures and graft –host junction ectasia, while in the other two patients after 1 and 2 months following surgery due to traumatic dehiscence. In DALK group resuturing was done in 4 out of 15 patients, two patients following graft dehiscence at 1 and 3 months postoperatively and other two patients with unstable graft-host junction due to loose sutures at 1 and 4 months postoperatively.

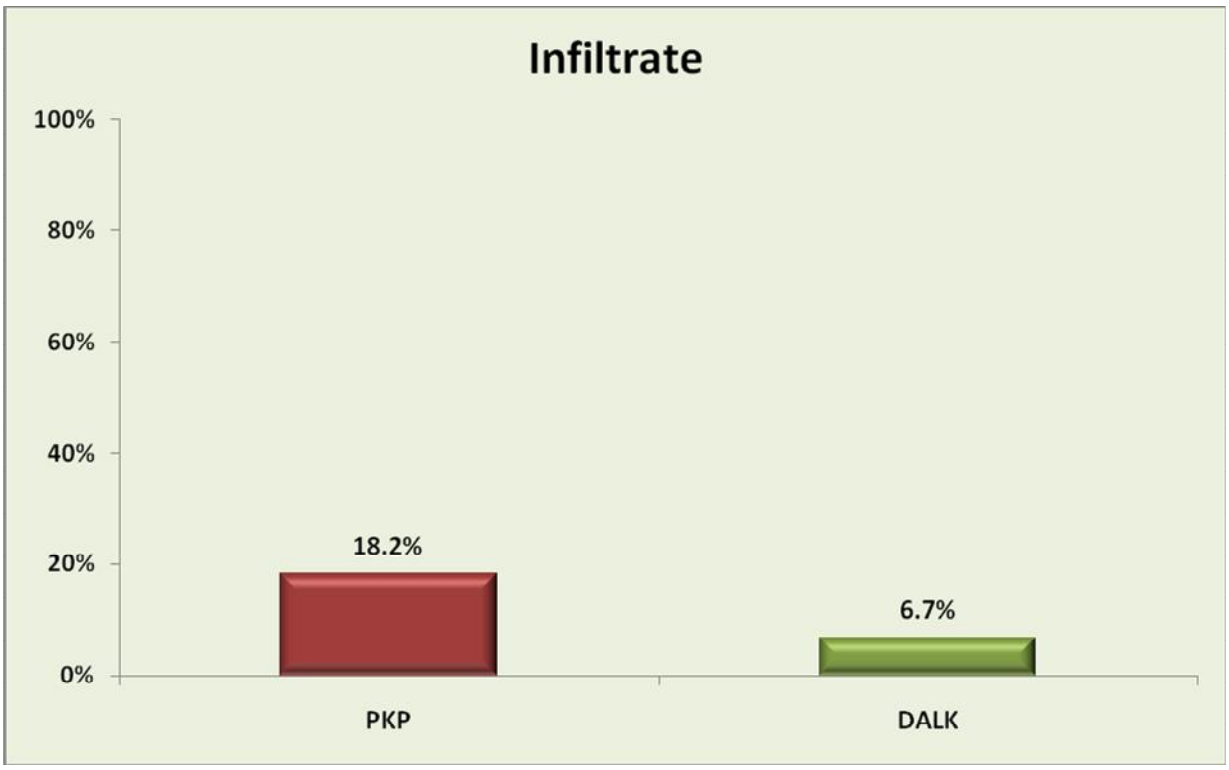
Post-op complication	**PKP**		**DALK**	
	n	**%**	**n**	**%**
Re-suturing				
Yes	3	27.3	4	26.7
No	8	72.7	11	73.3



INFILTRATES:

Post operative infiltrates in the graft were present in 2 patients in PKP group and 1 patient in DALK group. They were treated with topical antibiotic drops and the infiltrate resolved in all 3 cases. A bacterial/ sterile etiology was suspected.

Post-op complication	PKP		DALK	
	n	%	N	%
Infiltrate				
Yes	2	18.2	1	6.7
No	9	81.8	14	93.3



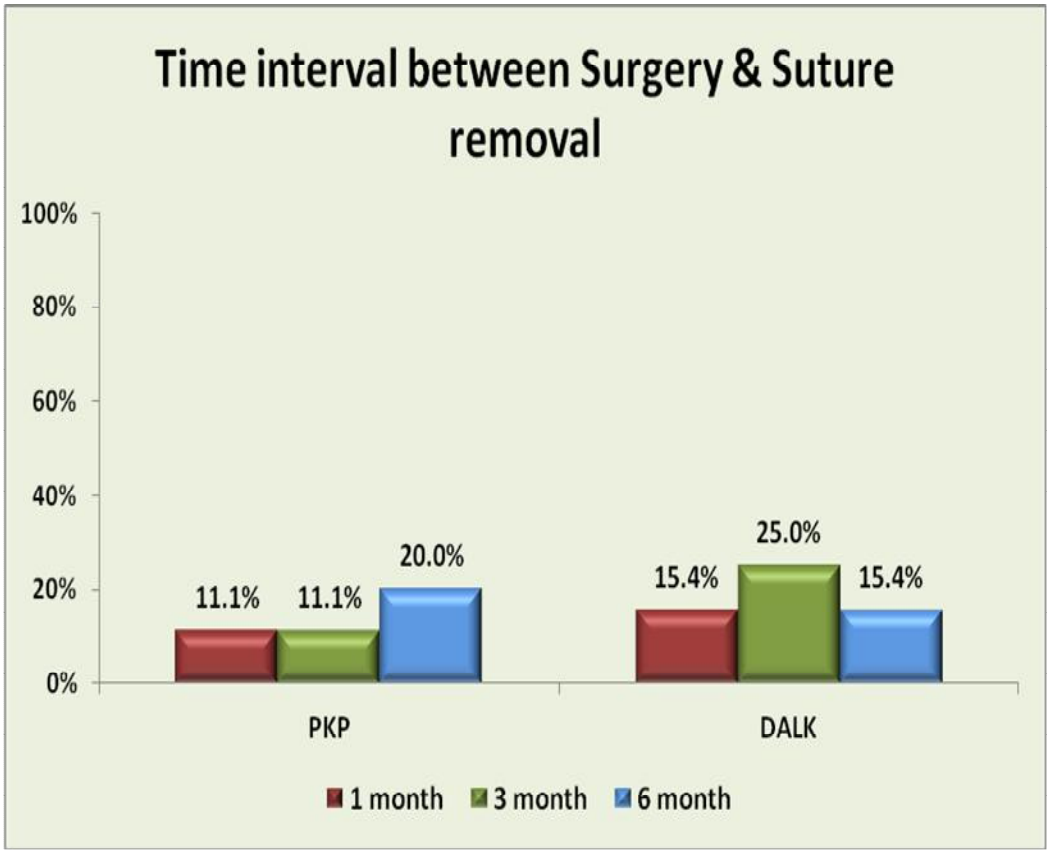
Other complications include epithelial defect, and interface haze. Interface haze was present in one patient in DALK group at 1 month postop, but spontaneously resolved in subsequent visit. Epithelial defect occurred in the immediate postoperative period in 2 patients but resolved by the next follow up visit. There was no persistent epithelial defect in any patients. Loose sutures were present in few patients, where suture removal was done.

Post-op complication	PKP		DALK		P-value
	N	%	n	%	
Day 1 ED Interface haze Graft unclear	 2 - 2	 18.2 - 18.2	 3 - 2	 20.0 - 13.3	-
1month ED Interface haze Graft unclear	 - -	 - -	 - 1	 - 6.7	-
3month ED Interface haze Graft unclear	 - -	 - -	 - -	 - -	-
6month ED Interface haze Graft unclear	 - -	 - -	 - -	 - -	-

TIME INTERVAL BETWEEN SURGERY AND SUTURE REMOVAL:

The suture removal was done for any loose or broken sutures. On comparision between the two groups, the suture removal was found to be earlier in DALK group compared to PKP group.

Post-op complication	PKP		DALK	
	n	%	n	%
Time interval between surgery and suture removal				
1month	1	11.1	2	15.4
3months	1	11.1	3	25.0
6months	2	20.0	2	15.4



DISCUSSION

Keratoconus, a progressive non inflammatory ectatic disorder of the cornea, mainly has its onset during puberty and progresses during second to third decade of life. Keratoconus causes visual morbidity in young people. The refractive error caused by the ectasia of the cornea is usually successfully treated with contact lenses. While RGP contact lenses remain the contact lens of choice, the newer contact lens design for keratoconus like Rose K lens, hybrid contact lens have improved the compliance of the patient for contact lens. Newer treatment modalities for keratoconus like corneal collagen cross linkage, intracorneal ring segments, phakic intraocular lens implantation, help to stabilize the vision and delay the need for keratoplasty surgery.

However around 10-20% of the keratoconus patients eventually progress and require keratoplasty surgery for reasons like poor visual acuity due to scarring of corneal stroma in visual axis, contact lens intolerance or poor visual acuity even after contact lens correction. Keratoplasty generally carries a good prognosis in keratoconus patients with good recovery of vision.

Penetrating keratoplasty is the well established and long time followed surgical treatment option for keratoconus. However deep anterior lamellar

keratoplasty procedure is now preferred by many surgeons instead of full thickness penetrating keratoplasty. DALK is considered as a better alternative to PKP since it preserves the host endothelium and eliminates the problem of postoperative endothelial rejection. Lamellar transplantation, largely being an extraocular procedure, has several advantages, such as reduced risk of intraocular complications like retinal detachment, expulsive hemorrhage and endophthalmitis.

The biggest hurdle to DALK adoption seems to be the significant learning curve. DALK is technically difficult and takes longer time to perform. The interface irregularity and the haze arising from manual lamellar dissection results in suboptimal visual outcomes. But recent improvement in surgical techniques of corneal lamellar dissection has improved the optical quality of vision with lamellar corneal surgeries.

Superior post operative vision with DALK compared to PKP has been found in few studies.[75,76] Several other studies have reported comparable visual outcomes with the two procedures.[35,77-79] And some studies have reported inferior visual outcome after DALK.[80,81]

We undertook this study to scientifically document and analyze differences in visual outcomes primarily and complications secondarily

between PKP ,which is the standard procedure and DALK ,which is a relatively newer procedure in the surgical management of keratoconus.

The mean age of the patients who underwent PKP and DALK in our study was 19.45 yrs and 17.86 yrs respectively, We see a lot of patients with advanced keratoconus in their teens and thus the younger age of our study subjects is in keeping with that trend. The main indication for keratoplasty surgery in our study is poor visual acuity due to visually significant corneal scarring, which was present in 25 of the 26 patients.

The preoperative mean BCVA in PKP group was 1.13±0.32 and in DALK group was 1.14±0.38, and this was not statistically significant.

Visual acuity:

The mean Snellen converted logMAR BCVA for PKP group was 1.13± 0.32, 0.51 ± 0.21, 0.34 ± 0.13 and 0.33 ±0.14 at baseline, 1 month, 3 months and 6 months respectively.

The mean Snellen logMAR BCVA for DALK group was 1.14 ± 0.38, 0.77 ± 0.26, 0.64 ± 0.29, and 0.60 ± 0.30 at baseline, 1 month, 3 months, and 6 months respectively.

There was a significant statistical difference in visual acuity between the two groups at end of 1month, 3 months and 6 months (P value less than 0.05). There was better visual acuity in PKP group than DALK group at end of 6 months postoperatively which is statistically significant.

At end of 6 months, 90.9% of the patients of PKP group has vision better than 6/18 while in DALK group only 46.7% of the patients has vision better than 6/18. The study by Watson et al [81] , showed that the median visual acuity of 6/6 for patients with keratoconus undergoing PKP is higher than for those receiving DALK, with 64% of PKP group having vision of 6/6 or better, while in DALK group only 32% had vision of 6/6 or better in their study. A recent study by Kasbekar S et al,[82] retrospective multicenter cohort study, found a greater proportion of patients achieved 6/6 or better snellen acuity following PKP than DALK, but no difference between the two groups was noted for the proportion of BCVA of 6/60 or less.

Penetrating keratoplasty is a well established procedure for treatment of various corneal conditions with a proven track record and excellent visual rehabilitation. BCVA of 6/12 or better has been reported in as high as 86% to 95% of the eyes undergoing PKP.[83,84] Studies comparing PKP with DALK have shown comparable visual outcome but a higher proportion of patients

with PKP achieve a BCVA of 6/6 postoperatively.[80,81] In a study by Funnel et al ,[80] 70% of patients undergoing PKP achieved a BCVA of 6/6 or better, compared with 22% with DALK at the end of 1 year after surgery but with a higher reported astigmatism in the PKP group. In a retrospective cohort study comparing the outcomes of PKP and DALK in keratoconus, Han et al[79] noted a BCVA of 6/6 or better in 67% of PKP group compared to 64.3% in DALK. Rice et al[85] confirmed that both PKP and DALK are successful surgical options for keratoconus but with attainment of better visual acuity after PKP as compared to DALK. They also reported similar rejection rates but faster visual rehabilitation in DALK cases compared to PKP.

However, other investigators have not noted this difference. Trimarchi et al[76] compared 150 cases of DALK , with a similar number of cases matched for PKP, and reported the mean visual acuity to be higher in patients having DALK. Similarly Tan et al,[75] showed that DALK gives significantly better visual outcomes compared to PKP for a heterogenous group of stromal pathologies.

The reason for the suboptimal visual acuity outcome for DALK patients in our study could be that the majority of our patients underwent manual technique of DALK. Many studies have shown inferior visual acuity outcome

with manual technique of DALK as compared to Anwar's big bubble technique. The reasons for suboptimal visual acuity outcome following manual technique are residual stromal layer, interface irregularity and residual scarring.

In an study by Adelkader et al[86] where they compared the visual outcome after manual technique or predescemetic DALK and descemetic DALK ,the study showed no significant difference in mean visual outcomes after 6 months of surgery. In the predescemetic eyes, the remaining fine layers of the stroma were clear and healthy. The interface haze progressively declined over time and was not sufficient to compromise the visual acuity of these patients. Ardjomand et al[87] demonstrated that the quality of vision in postgraft keratoconus eyes is correlated to the thickness of the residual recipient stromal bed. The study showed that an eye following DALK and residual bed of less than 20 microns can achieve visual result similar to PKP, whereas those with a recipient thickness of more than 80 microns has significant reduced visual acuity.

In our study the refractive astigmatism at the end of 6 months ranged from -6.00 to +5.50DC in PKP group and -3.00 to +2.00DC in DALK group. The spherical equivalent at the end of 6 months ranged from -3.00 to 2.75 diopters sphere (DS) in the PKP group and -5.5 to 3.5 DS in the DALK group.

In the study by Kasbekar S et al.[82], they noted a significant difference in postoperative refractive error between PKP and DALK group, with more myopic mean refractive error in DALK patients. The Watson et al study[81], also showed the median spherical equivalent of both the groups with mild myopia, although the DALK group was more myopic. However some of the other studies showed no significant difference in refractive astigmatism and spherical equivalent between PKP and DALK.[79, 80]

In our study the mean keratometric astigmatism at the end of 6 months was 7.78D and 9.42D in PKP and DALK group respectively. However in our study complete suture removal was not done for any patient at the end of 6 months. Because suture removal is likely to influence astigmatism values, a longer follow-up is needed to evaluate final astigmatism values after suture removal.

Complications:

The main complications noted in our study are graft dehiscence, postoperative infection and resuturing. Graft dehiscence occurred in 2 patients in PKP group following trauma, and 2 patients in DALK group, one following trauma and the other occurred spontaneously. All the four patients underwent

resuturing of graft. The visual acuity was better in all the four patients at the end of 6 months.

In Penetrating keratoplasty there is a full thickness 360 degree surgical wound of the cornea and this causes a permanent weakness of the eyeball. But in DALK, descemet's membrane and endothelium are kept intact and so it is suggested that the wound healing will be faster and more durable than PKP. Stronger graft host interface formation may be provide by uninterrupted endothelium, healthier restoration process and reduced need for topical steroids. Some of the risk factors for the graft host interface weakness are inappropriate wound apposition, improper suturing, early suture removal, avascularity of the interface, and prolonged treatment with steroids. In Esin Sogutlu Sari et al[88] study of traumatic wound dehiscence after deep anterior lamellar keratoplasty, the incidence of traumatic wound dehiscence was found to be 3.2%. This finding is similar to that of other PKP series in which the incidences have been reported between 0.6% and 5.8%. The mean interval between the initial DALK procedure and wound dehiscence was 9.45 months in this study. However, it was claimed that posttraumatic visual outcomes seem to be better in DALK cases.

Resuturing of the graft was done when there was threat to the stability of the graft like in graft dehiscence, multiple loose sutures with unstable graft host junction. In PKP group resuturing was done in 3 out of 11 patients(27.3%) and in DALK group resuturing was done in 4 out of 15 patients (26.7%).

Post operative infiltrates in the graft were noted in 2 patients in PKP group and 1 patient in DALK group. They were treated with frequent topical antibiotic drops and the infiltrate resolved in all 3 cases with medications.

Interface haze was present in one patient post DALK at 1 month, but was found to have resolved at the end of 6 months. Interface haze has been reported in many of the studies. With the advent of newer techniques like big bubble technique of DALK where dissection is completed till the descemet's membrane, the frequency of interface haze has decreased.

In DALK, there is a reduced need for topical medications, where the topical steroids can be stopped earlier than PKP. So there may be a lower risk of associated complications such as cataract, glaucoma and allergies. In our study we did not find any cataract changes and glaucoma developing after the surgery within the 6 months period of follow up. Although we did see IOP spike due to a possible steroid response in few patients in both PKP and DALK

group, but these were controlled with short term use of antiglaucoma medications.

Graft rejection, a dreaded complication of keratoplasty surgery, was not noted occurred in our study. In DALK, where the endothelium is retained, there are reduced chances for graft rejection and theoretically lower risk for late corneal decompensation with DALK. Many studies shows lower graft rejection rates following DALK compared to PKP .[79,81] In Kasbekar S[82] et al study, there was no significant difference in the overall graft survival between PKP and DALK, 92% for PKP and 90% for DALK. The causes for graft failure following DALK were rejection (mainly stromal rejection), infection and intra operative surgical complications. This study also shows that the presence of ocular surface disease increased the risk of graft failure following DALK. There was no significant difference in the mean time to graft failure following PKP and DALK in this study.

In the current era, many advocate the procedure of DALK over PKP with most studies reporting similar post operative visual acuity and graft survival. The main advantage of DALK procedure is the retention of the healthy endothelium of the recipient. Thus retention of the patient's own endothelium eliminates the chances of endothelial rejection, which is one of the

major reason for graft failure. However the chances for stromal and epithelial rejection are possible in DALK. But there are studies showing no significant difference in graft survival following PKP and DALK.[81,82] in our study there was no graft rejection following both PKP or DALK in 6 months follow up.

Some studies comparing the outcomes of PKP and DALK noted a comparable or even better results with DALK.[78-80] Kasbekar S et al[82] in their study, found that the greater proportion of patients attained 6/6 vision following PKP than DALK procedure, similar to the Watson et al[80] study. The study also analyzed the visual outcome in regard to surgeon experience and found that there was no significant difference between the mean refractive error and surgeon experience. This study also found the slow uptake of DALK for keratoconus in United Kingdom, increasing from 9% to around 40% between 2008 and 2012, in contrast to rapid uptake of endothelial keratoplasty (around 85%), thus reflecting slightly better visual outcome with PKP than DALK for patients with keratoconus. In our study also there is a significant difference between the visual outcome following PKP and DALK, with better visual outcome with PKP than DALK procedure in 6 months follow up

In conclusion, though DALK seems to offer advantages over PKP, by preserving endothelium and avoids potential intraocular damage that can be

associated with PKP, the visual outcome is still debatable. Despite the modification of technique of performing DALK there is still unpredictability in graft survival and refractive outcome following DALK. Our study gives a better visual outcome following PKP with equal complication rates in both PKP and DALK procedures.

SUMMARY

In our study:

- The mean age of the patients in the PKP and DALK group was 19.45years and 17.86 respectively.
- In both the groups male preponderance was noted.
- Corneal apical scar was present in 25 out of 26 patients, preoperatively.
- The mean keratometric astigmatism at 6 months postoperatively was 7.78± 4.43 and 9.42 ±6.27 in PKP and DALK respectively.
- There was a statistically significant difference in visual acuity between the two groups, with better visual acuity after PKP than DALK surgery at end of 1month, 3 months and 6 months (P value less than 0.05).
- The major postoperative complications in our study were graft dehiscence, Infiltrates in the graft and increase in IOP postoperatively. The complications were equal and comparable in both the groups.

LIMITATIONS OF OUR STUDY

1. The sample size of 26 eyes in our study is a small number and so the interpretation of results may vary with other studies.

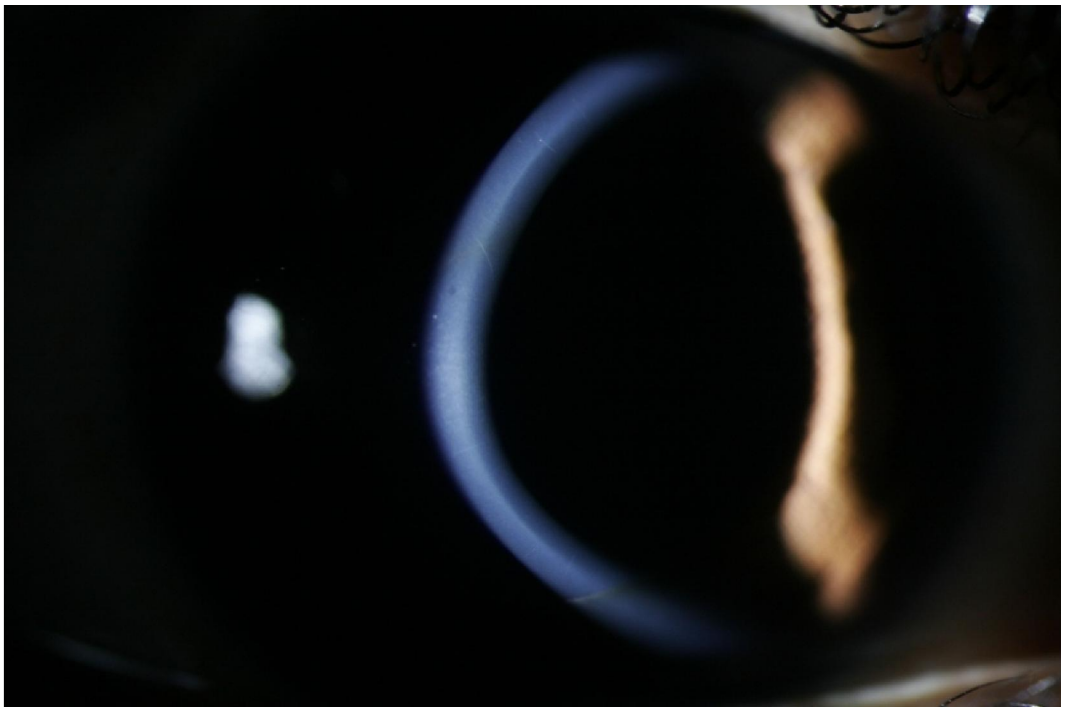
2. Long term follow up is required to assess the graft survival after the surgery. Follow up period of 6 months is one of the shortcomings of the study.

3. Comparision of endothelial cell count preoperatively and post operatively would have given better idea about rate of endothelium loss after PKP and DALK.

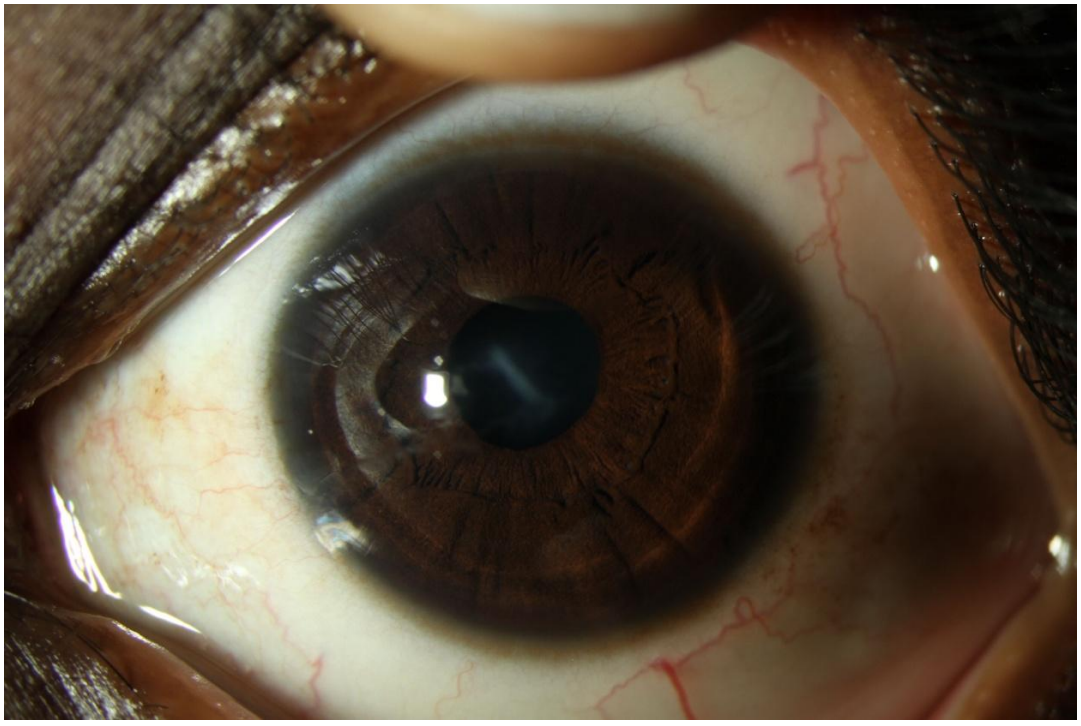
4. Sutures were not removed in all the patients at the final follow up, so the actual visual outcome may vary when all the sutures are removed.

CONCLUSIONS

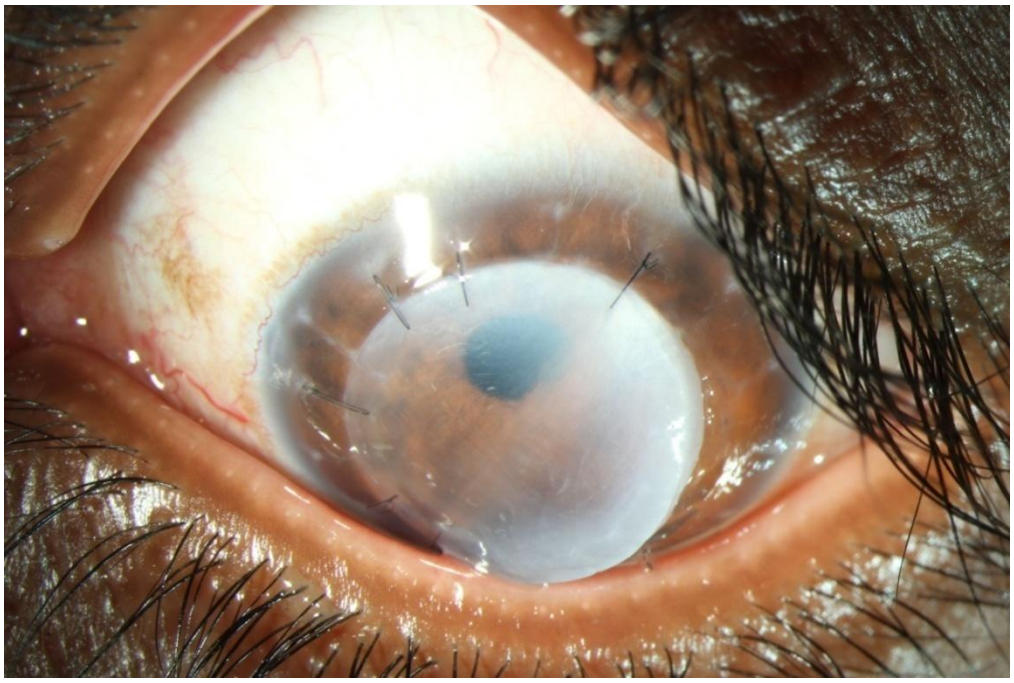
In conclusion, though lamellar keratoplasty is considered one of the recently introduced and effective alternative procedures for keratoconus, penetrating keratoplasty may well remain the gold standard surgical procedure for keratoconus as our results show. DALK theoretically offers many advantages over conventional PKP like preservation of the host endothelium and allowing earlier discontinuation of steroids thereby reducing the incidence of cataract and glaucoma. Also endothelial graft rejection which is a significant cause for graft failure will not occur post DALK. Though the visual results after DALK were found to be comparable to those of PKP in some studies, the percentage of patients with BCVA of 6/6 or better were less in the DALK group, indicating that visual outcomes with PKP were better overall. A larger cohort of patients with a longer period of post operative follow up might have shown different results. Most corneal surgeons are comfortable performing PKP while many surgeons have a limited experience performing DALK which is technically more challenging. Many recent studies have compared the two procedures and our study though small adds to the knowledge.



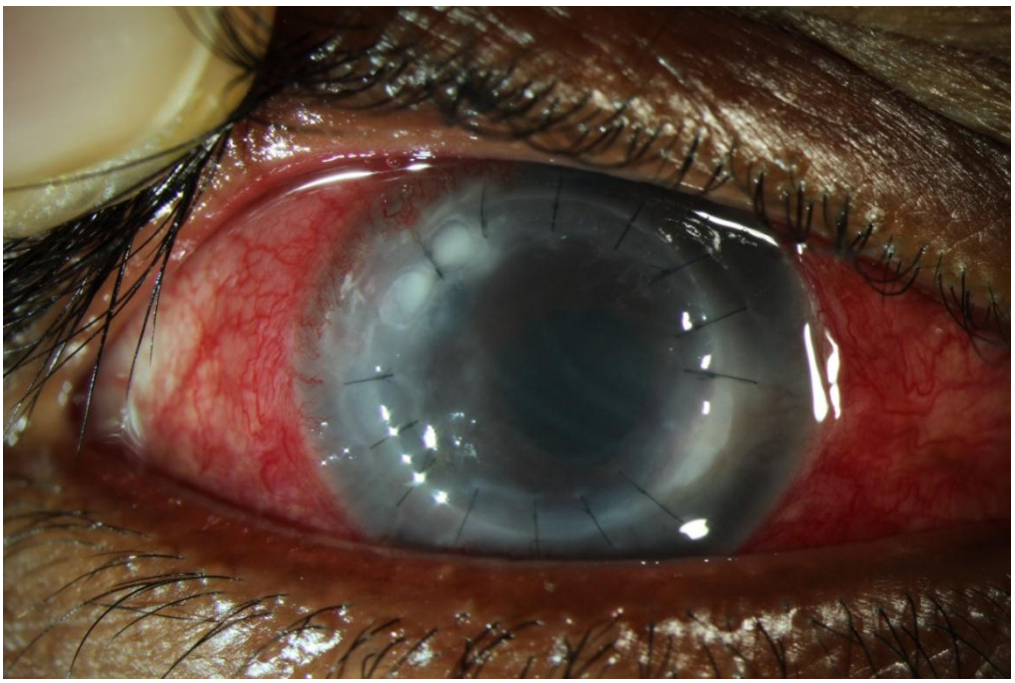
SLIT LAMP PHOTO SHOWING KERATOCONUS



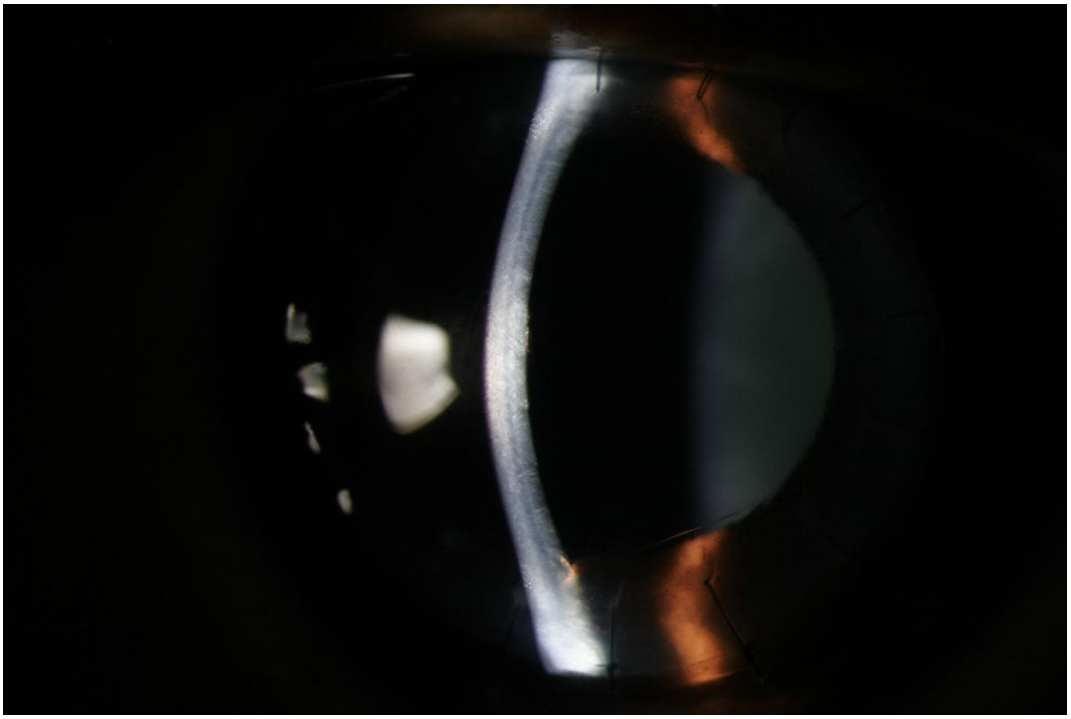
SLIT LAMP PHOTO SHOWING CORNEAL APICAL SCAR



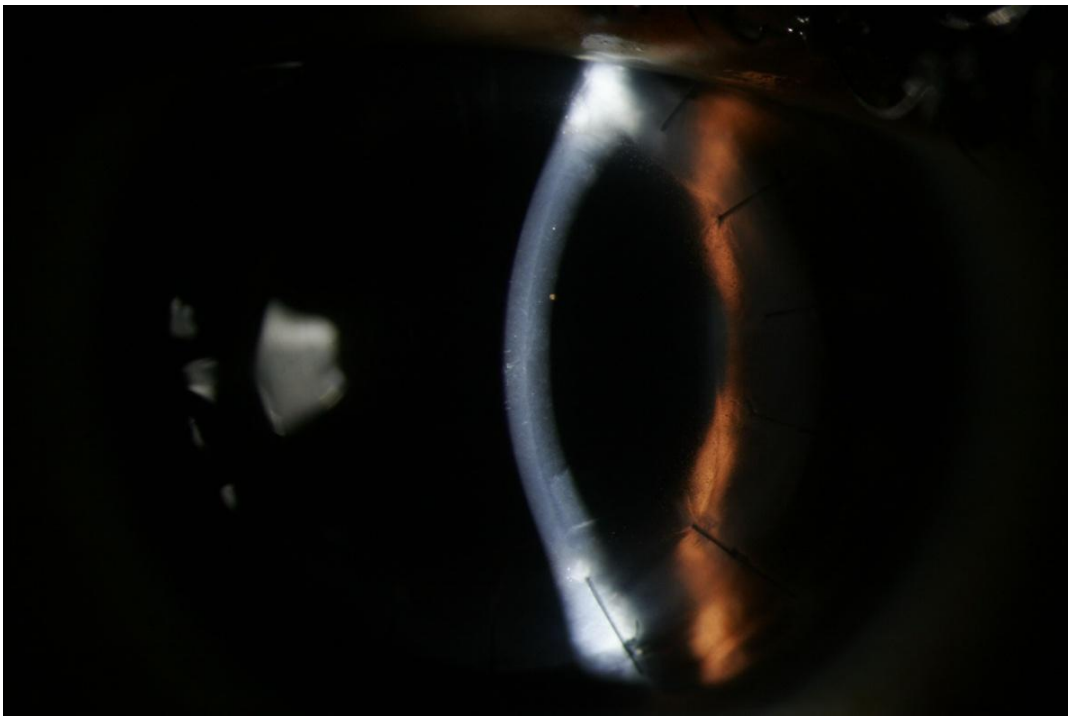
CLINICAL PHOTO OF THE EYE SHOWING GRAFT DEHISCENCE



CLINICAL PHOTO OF THE EYE SHOWING INFILTRATE FOLLOWING DALK

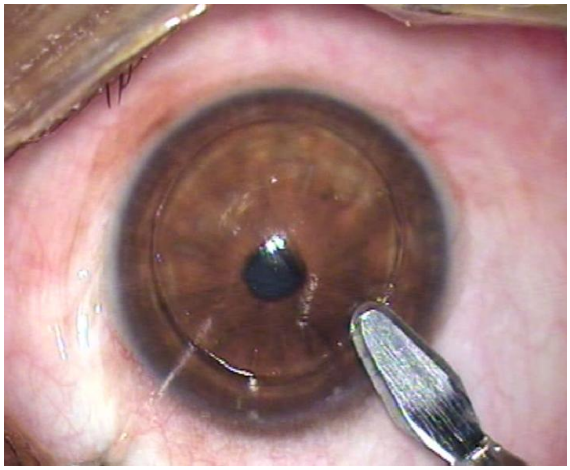


INTERFACE HAZE AT 1 MONTH

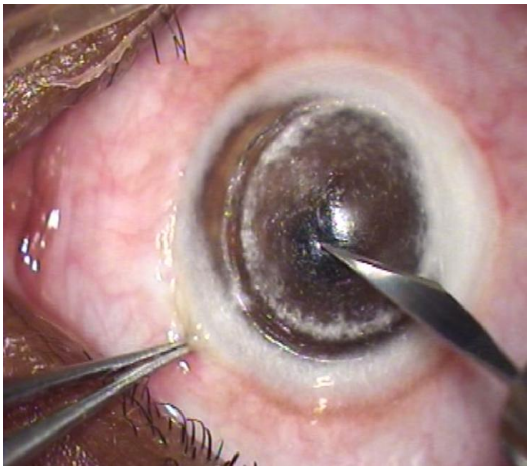


INTERFACE HAZE HAS RESOLVED BY 3 MONTHS

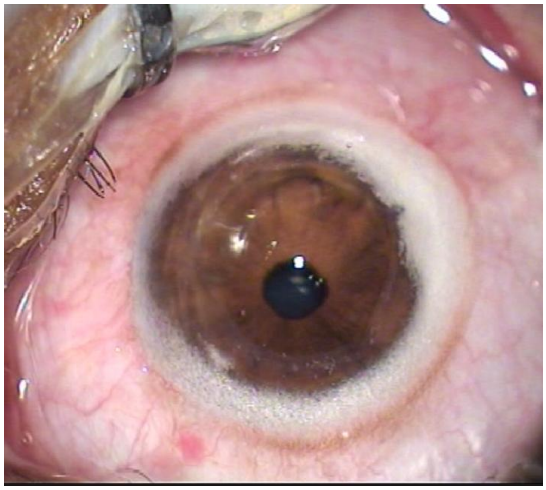
BIG BUBBLE TECHNIQUE OF DALK



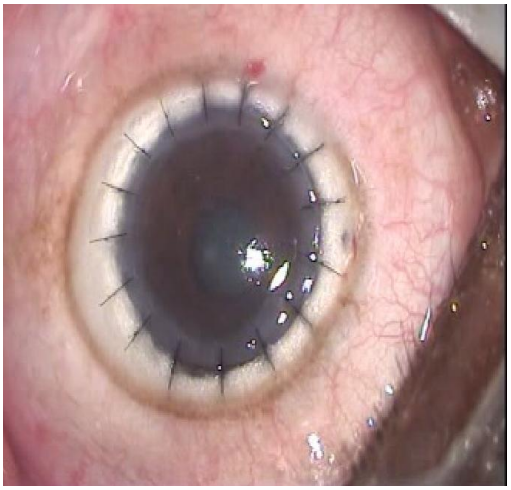
PARTIAL STROMAL DISSECTION BEFORE DOING INJECTING BIG BUBBLE



BIG BUBBLE IS BEING DECOMPRESSED WITH THE KERATOME



BARED DESCEMET'S MEMBRANE AFTER CUTTING THE OVERLYING STROMA WITH SCISSORS



RECIPIENT TISSUE SUTURED TO THE HOST CORNEA

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PROFORMA

SERIAL NO: DATE:

NAME: AGE/SEX:

MR. NO:

ADDRESS:

PHONE NO:

COMPLAINTS:

H/O vernal keratoconjunctivitis/allergy yes/no

H/O Contact lens use yes/no

Type: of CL –RGP/Hybrid/Rose k Years: intolerance/inappropriate

H/O Trauma yes/no

H/O Previous surgical treatment Intacs/LASIK/C_3R

H/O Medications

SYSTEMIC HISTORY: DURATION

Diabetes Mellitus yes/no

Hypertention yes/no

Collagen vascular disorders yes/no

Immunocompromised state yes/no

Bronchial asthma/Hay fever yes/no

OCULAR EXAMINATION:

Visual Acuity	RIGHT EYE	LEFT EYE
UCVA		
BCVA		
VA with RGP CL		

Right Eye Left Eye

Eye Lids:

Lacrimal apparatus:

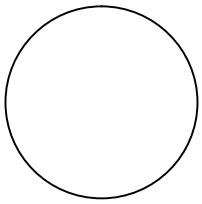
Slit Lamp Examination:

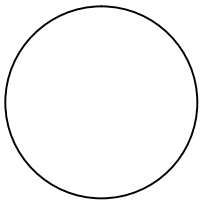
Conjuctiva

Cornea

Type of cone :

Oval/nipple/globus





Striae

Fleischer's Ring

apical scar/deep scar

DM breach

Anterior Chamber

Iris

Pupil

Lens

Fundus:

Refraction:

	Spherical	Cylinder	Axis	V/A
Right Eye				
Left Eye				

Scissors shadow/ Oil droplet reflex

Intraocular Pressure: Right Eye Left Eye

Keratometry Reading: Right eye

Left eye

Orbscan/ Pentacam: Right Eye Left Eye

K readings	K1 K2	K1 K2
Central Corneal Thickness		
Anterior Float		
Posterior Float		

DIAGNOSIS: RE LE

Treatment Advised: RE/LE PKP/DALK

SURGICAL DETAILS:

Date of surgery:

Eye : Right / Left

Anaesthesia : General anaesthesia/Local anaesthesia

Technique : PKP

DALK-

- Big Bubble
- Manual Lamellar

Residual Stromal Bed: yes/no

Graft size/Disparity:

Suture technique: interrupted/continuous

No. of sutures :

❖ PKP

- INTRAOPERATIVE Complication:

YES / NO

- Improper trephination
- Damaged Donor button
- Excessive bleeding
- Injury to Iris –lens diaphragm

- POST OPERATIVE Complication: Immediate Early Late

- Shallow AC
- Wound leak
- Suture - loose/tight
- Hyphaema
- Epithelial defect
- Glaucoma
- Primary graft failure

❖ DALK:

- Intraoperative Complication YES / NO
    - Micro perforation
    - Conversion to PKP

- POST OPERATIVE Complication:
    - Interface Haze
    - Interface separation/ Detached DM
    - Secondary Glaucoma
    - Secondary Cataract
    - Secondary procedure/ resurgery

FOLLOW UP

	Immediate Post operative			1 month			3 months			6 months		
Date												
UCVA												
BCVA												
Refractive Astigmatism	sphere	Cylinder	axis	sphere	cylinder	axis	sphere	cylinder	axis	sphere	cylinder	axis
IOP												

SLITLAMP EXAMINATION

Conjunctiva				
Epithelial defect				
Interface Haze				
DM fold				
Graft clarity				
Graft infection				
Sutures (loose/broken)				
Suture abscess				
Anterior chamber				
lens				
FUNDUS				

Suture Removal :

Keratometry reading : <u>1 month post op:</u>

Right eye:

Left eye:

<u>3 months post op:</u>

Right eye

Left eye

ORBSCAN: 6 months post op:

K reading	**K1**	**K1**
	K2	**K2**
Central corneal thickness		

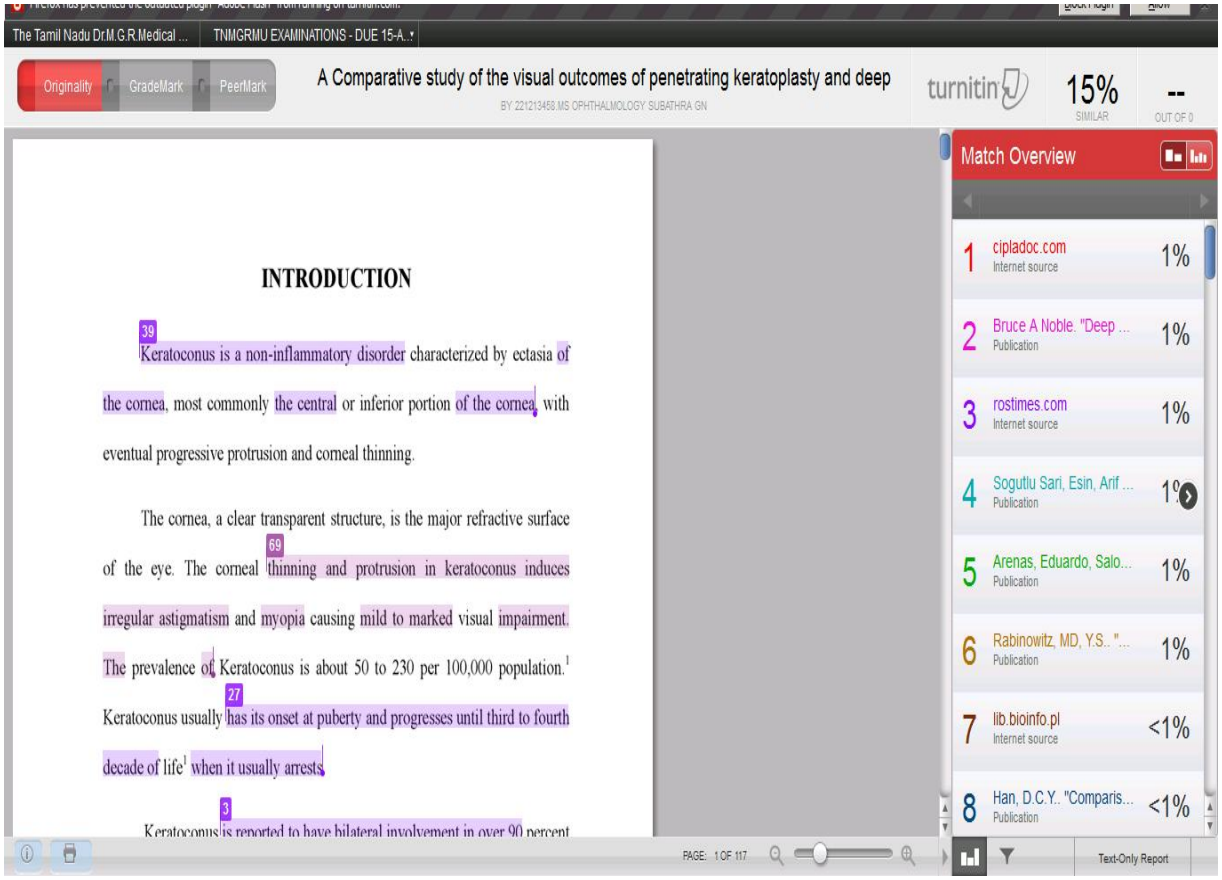
ABBREVIATIONS

DALK	:	Deep anterior lamellar keratoplasty
PKP	:	Penetrating keratoplasty
VA	:	Visual acuity
BCVA	:	Best corrected visual acuity
UCVA	:	Uncorrected visual acuity
IOP	:	Intraocular pressure
CL	:	Contact lens
SD	:	Standard deviation
SE	:	Spherical equivalent

								Pre-op						Apical scar	IOP	Fundus	Keratometry		Topography			Intra-op					Post OP					
SNO	**MR NO**	**Name**	**age**	**sex**	**eye**	**CL use**	**previousc3r**	UNVA	Sphere	Cyl	Axis	BCVA	RGP CL VA				K1	K2	K1	K2	CCT	Date of surgery	procedure	Graft size/disparity	suture	complication	UCVA	ED	Interface haze	Graft clarity	sutures	Resuturing
1	3481026	saikrishna	12	M	RE	No	No	2/60	-14.5	-4	60	2/60	6/60	yes	Err	Normal	61.48@16	83.30@106	61.5@114	56.8@24	394	3/5/2013	DALK	8.2/0.2	16 interrupted	no	5/60	yes	No	DMF+	intact	
2	3575331	vishal choudary	16	M	RE	No	No	1/60	-18.0			5/60	NA	yes	err	Normal	>60.0	>60.0	NA	NA	NA	16/5/2013	DALK	8.2/0.2	16 interrupted	no	6/60	No	No	clear	intact	
3	3589003	Ajay kumar	19	M	LE	No	No	3/60	Nig			3/60	6/12	yes	err	Normal	> 60.0	>60.0	NA	NA	NA	28/5/2013	PKP	8/0.2	16 interrupted	no	6/60	no	no	clear	2 loose sutures	YES
4	3574749	Murali	17	M	LE	No	No	1/60	-12.0	-4.0	180	6/36	6/9	yes	13	normal	NA	NA	65.9@122	63@32	370	28/5/2013	DALK	8.25/0.2	16 interrupted	no	6/60	yes	no	clear	intact	
5	2626114	Yogamoorthy	14	M	RE	No	No	2/60	-4.0	-4.0	180	5/60	NA	yes	err	Normal	>60.0	>60.0	NA	NA	NA	30/5/2013	PKP	8.5/0.2	16 interrupted	NO	6/18	No	NO	clear	intact	
6	3596641	Divya singh	22	F	LE	YES	No	6/60	Nig			6/60	6/24	yes	14	Normal	NA	NA	52.62@118	47.51@28	368	5/6/2013	DALK	8.2/0.2	16 interrupted	no	6/60	no	no	clear	intact	
7	3578230	Rajin.P.T	20	M	RE	YES	No	3/60	-8.0	-2.50	15	6/60	6/36	yes	err	Normal	>60.0	>60.0	70.5	85.0	387	8/6/2013	PKP	7.7/0.2	16 interrupted	no	2/60	yes	No	clear	intact	
8	3606675	Anil kumar	15	M	LE	YES	No	6/60	Nig			6/60	6/9	yes	Err	Normal	>52.0	>52.0	NA	NA	NA	24/6/2013	DALK	8.0/0.2	16 interrupted	no	6/60	No	No	clear	intact	
9	2512645	Krishna kumar		M	RE	YES	No	2/60	-18.0			6/36	NA	yes	err	Normal	NA	NA	NA	NA	NA	27/6/2013	DALK	7.5/0.2	16 interrupted	no	6/36	No	No	clear	intact	
10	3601085	Melvin johnson	15	M	RE	No	No	5/60	Nig			5/60	6/36	yes	16	Normal	>52.0	>52.0	NA	NA	NA	12/7/2013	PKP	8.5/0.5	16 interrupted	no	6/18	No	No	clear	intact	
11	3612192	Lakshmi narayanan	20	M	LE	No	No	3/60	Nig			3/60	6/12	yes	20	Normal	62.25@25	60.25@115	73.3	63.5	173	29/6/2013	PKP	8.0/0.2	16 interrupted	no	6/18	No	No	DMF+	intact	
12	3508045	Vaishnavi.S	22	F	LE	No	No	5/60	Nig			5/60	6/18	yes	err	Normal	>60	>60	NA	NA	NA	1/7/2013	PKP	8.5/0.5	16 interrupted	no	6/60	No	No	clear	intact	
13	3615715	Hussain Mohamed	25	M	RE	No	No	3/60	Nig			3/60	6/36	yes	err	Normal	>60	>60	59.1	66.8	158	18/7/13	PKP	8.25/0.2	16 interrupted	NO	6/24	No	No	clear	intact	
14	3600208	Pandi.V	12	M	LE	No	No	2/60	-10	-2.50	160	6/60	6/9	yes	13	Normal	57.37@140	60.12@50	54.8	58.1	365	20/7/13	DALK	8.2/0.2	16 interrupted	no	5/60	No	No	clear	intact	
15	3610553	Indirani.I	31	F	LE	No	No	6/24	Nig			6/24	6/12	yes	err	Normal	NA	NA	57.9	62.0	286	20/7/13	PKP	7.7/0.2	16 interrupted	no	5/60	No	No	clear	intact	
16	3626963	Shaik Mahaboob Basha	26	M	RE	No	No	4/60	Nig			4/60	6/12	yes	err	Normal	>52	>52	73.6	83.8	307	24/7/13	DALK	8.2/0.2	16 interrupted	no	6/60	No	No	clear	intact	
17	3640308	Shanifa Noushad	20	F	RE	No	No	1/60	Nig			1/60	6/24	yes	err	Normal	>52	>52	74.4	89.4	214	15/8/13	PKP	8.0/0.2	16 interrupted	no	6/24	YES	No	clear	intact	
18	2426656	Sridhar.G	21	M	RE	YES	No	2/60	Nig			2/60	NA	yes	8	Normal	66.75@155	62.25@65	NA	NA	NA	29/8/13	DALK	8.2/0.2	16 interrupted	no	6/24	No	No	clear	intact	
19	2358044	Balachandran	20	M	LE	No	No	1/60	-18.0	-4.50	150	6/18	6/12	yes	Err	Normal	54@170	59@80	NA	NA	NA	6/9/13	DALK	8.2/0.2	16 interrupted	no	6/60	No	No	clear	intact	
20	3636239	Anish.K	30	M	LE	No	No	1/60	Nig			1/60	6/60	yes	12	Normal	>50	>50	88.2	99.2	188	4/10/13	DALK	7.7/0.2	16 interrupted	no	6/60	No	No	DMF+	intact	
21	3168894	Sakthivel.D	15	M	RE	No	No	3/60	-4.0	-5.0	15	6/36	6/12	yes	err	Normal	>50	>50	NA	NA	NA	16/10/13	PKP	8.1/0.2	16 interrupted	no	6/12	No	No	DMF+	intact	
22	3652218	Mariya Thankachan	17	F	RE	YES	No	2/60	Nig			2/60	6/24	No	16	Normal	NA	NA	68.0@8	72.7@98	350	26/10/13	DALK	8.2/0.2	16 interrupted	no	6/36	NO	NO	clear	intact	
23	3677644	iswarya	15	F	RE	No	No	1/60	Nig			1/60	NA	yes	err	Normal	>60	>60	66.7@30	72.3@120	199	13/11/13	DALK	8.2/0.2	16 interrupted	no	6/60	no	no	clear	intact	
24	3682409	Malayandi	17	M	LE	No	No	6/36	Nig			6/36	6/9	yes	err	Normal	62.75@5	65.50@95	NA	NA	NA	13/11/13	DALK	8.0/0.2	16 interrupted	no	6/18	no	No	clear	intact	
25	3683454	Harsha Vardhan	10	M	LE	No	No	2/60	-15	-2.50	165	6/60	6/18	yes	8	Normal	64.90@119	68.46@29	62.7@161	66.5@71	288	22/11/13	DALK	8.25/0.2	16 interrupted	no	5/60	yes	No	clear	intact	
26	3751323	Thamaraiselvi	13	F	RE	No	No	FCF	Nig			FCF	NA	yes	err	Normal	NA	NA	NA	NA	NA	03/03/14	PKP	8.5/0.5	16 interrupted	no	6/36	No	No	clear	intact	

1 Month- Follow up											Keratometry		RESUTURING	3 Month- Follow up										Keratometry	
Sr.No.	UNVA	Sphere	Cyl	Axis	BCVA	Graft clarity	Sutures	IOP	suture removal	Resuturing	K1	K2		Sr.No.	UCVA	Sphere	Cyl	Axis	BCVA	Graft clarity	sutures	IOP	suture removal	Resuturing	K1	K2
1	6/60	nig			6/60	DMF+	intact	14	no		38.93@124	43.16@34		1	6/60	nig			6/60	clear	intact	29	NO		NA	NA
2	6/36	nig			6/36	clear	intact	20	no		36.29@89	44.23@179		2	6/36	nig			6/36	clear	intact	NA	NO		NA	NA
3	5/60		+4.50	140	6/18	clear	intact	19	no		45.50@165	32.0@75		3	5/60		+5.0	180	6/12	clear	intact	20	NO		45.50@165	34.50@75
4	6/60		+3.0	165	6/24	clear	intact	20	no	YES	36.21@86	51.37@176	yes	4	6/36		+2.50	105	6/18	clear	intact	20	yes		NA	NA
5	6/18	nig			6/18	clear	intact	14	no		NA	NA		5	6/24	-1.50	-3.0	180	6/12	clear	intact	14	NO		NA	NA
6	6/36	nig			6/36	clear	intact	16	no		NA	NA		6	6/36		+2.00	120	6/12	clear	intact	16	NO		42.5@80	47.0@170
7	6/60		-3.0	180	6/24	dehiscence	3 loose sutures	18	no	YES	41.50@145	50.50@55	yes	7	5/60		-3.0	180	6/24	clear	intact	23	NO		NA	NA
8	6/36	nig			6/36	clear	intact	9	no		52.0@180	36.0@90		8	6/36	nig			6/36	clear	1 broken suture	9	yes		52.0@180	36.0@90
9	6/36	nig			6/36	clear	intact	18	no		NA	NA		9	6/24	nig			624	clear	intact	16	NO		NA	
10	6/18	nig			6/18	clear	intact	11	no		NA	NA		10	6/18		+2.0	165	6/12	clear	intact	12	no		47.25@20	41.25@110
11	6/18	nig			6/18	clear	intact	20	no		43.25@160	39.0@70		11	6/24	+0.50	+3.0	140	6/9	clear	intact	11	NO		NA	NA
12	6/24	nig			6/24	clear	intact	19	no		NA	NA		12	5/60		-4.0	180	6/12	clear	intact	16	NO		NA	NA
13	6/60		-4.0	180	6/18	DMF+	intact	13	NO		NA	NA		13	6/60		-6.0	180	6/18	clear	intact	16	NO		NA	NA
14	6/60	nig			6/60	interface haze	intact	18	no		NA	NA		14	6/36	+3.0	+1.0	180	6/12	clear	intact	14	NO		41.5@90	44.5@180
15	6/36	nig			6/36	clear	1 loose suture	13	yes		55.75@135	36.0@90		15	5/60	+2.0	-6.0	110	6/18	clear	intact	17	NO		NA	NA
16	4/60		+4.0	180	6/60	clear	intact	24	no		36.97@87	47.67@172		16	5/60	nig			5/60	edema,DMF	4 Loose sutures	23	NO	yes	NA	NA
17	6/18	nig			6/18	clear	intact	14	no		NA	NA		17	6/12	nig			6/12	clear	intact	17	NO		40.13@113	46.81@23
18	3/60	-5.0	-3.0	120	6/24	interface folds+	intact	20	no		43.25@110	48.0@20		18	3/60	-5.0	-3.5	120	6/24	clear	intact	13	NO		43.72@114	50.68@24
19	5/60		-4.0	90	6/60	clear	2loose sutures	NA	yes	YES	NA	NA		19	5/60		-4.0	90	6/60	clear	2 loose sutures	NA	yes		NA	NA
20	1/60	+10.0			5/60	DMF+	intact	17	no		46.0@180	36.0 @90		20	2/60		+6.0	160	6/60	clear	intact	19	NO		46.0@180	36.0@90
21	6/9		-1.0	165	6/6	clear	intact	13	no		39.0@150	44.0@60		21	6/18		-1.0	180	6/12	dehiscence	intact	19	NO	yes	NA	NA
22	6/18	nig			6/18	clear	intact	19	no		NA	NA		22	6/18	nig			6/18	clear	intact	13	NO		42.25@70	48@160
23	6/60	nig			6/60	clear	intact	20	no		NA	NA		23	6/24	NIG			6/24	Clear	intact	18	no		50.5@165	41.5@75
24	6/12	nig			6/12	clear	1 loose suture	16	yes		NA	NA		24	6/12	nig			6/12	clear	intact	16	NO		NA	NA
25	6/36		+2.0	120	6/12	clear	intact	36	no		NA	NA		25	6/36		+2.0	120	6/12	Clear	intact	40	no		NA	NA
26	6/36	nig			6/36	clear	intact	14	no		NA			26	6/36	-1.0	-4.0	180	6/9	clear	2 loose sutures	12	yes		44.0@10	48.50@100

6 Months- Follow up										Keratometry		Topography		
Sr.No.	UCVA	Sphere	Cyl	Axis	BCVA	Graft clarity	sutures	IOP	suture removal	K1	K2	K1	K2	CCT
1	6/18		+2.0	45	6/12	clear	intact	16	no	40.0@150	44.0@60	44.4@39.7	40.6@129.7	639
2	6/36	nig			6/36	clear	intact	14	no	33.0@90	53.0@180	53.5@177	35.1@87	692
3	6/60		+5.50	155	6/9	clear	intact	19	no	38.0@70	44.0@160	37.6@71.7	43.7@161.7	481
4	6/36		+2.0	150	6/12	clear	intact	28	NO	39.43@112	50.42@22	51.8@26	40.4@116	639
5	6/36	-1.50	-3.0	180	6/9	clear	intact	17	no	42.75@160	50.50@70	NA		
6	6/36		+2.00	120	6/12	clear	intact	18	no	42.5@80	47.0@170	NA		
7	5/60		-3.0	180	6/24	Inf mild edema	intact	12	no	41.50@145	50.50@55	NA		
8	6/36	nig			6/36	edema,early infiltrate	3 loose sutures	NA	no	46.0@180	47.50@90	45.5@55	41.8@145	628
9	6/12	nig			6/12	clear	intact	18	no	46.25@30	54.25@120	NA		
10	6/18		+1.50	165	6/12	clear	intact	10	no	42@135	48.5@45	49.5@47	42.5@137	516
11	6/24	+0.50	+3.0	140	612	clear	1 loose suture	10	yes	35.60@66	45.24@156	37.9@50.7	46.3@140.7	492
12	6/36		-4.0	180	6/12	clear	intact	19	no	44.0@25	48.25@115	NA		
13	5/60		-4.50	180	6/12	clear	intact	16	no	41.25@15	49.25@105	47.7@103	40.1@13	459
14	6/36	+3.0	+1.0	180	6/12	clear	intact	15	no	41.5@90	44.5@180	NA		
15	5/60	+2.0	-6.0	110	6/18	clear	intact	17	no	55.75@180	36.0@90	NA		
16	6/36	nig			6/36	clear	1 loose suture	15	yes	35.0@70	52.75@160	59.6@87	41.3@177	609
17	6/9	nig			6/9	clear	intact	15	no	40.13@113	46.81@23	NA		
18	5/60	-4.0	-3.0	120	6/24	superior interface haze	intact	17	no	43.5@110	52.0@20	NA		
19	6/60	nig			6/60	clear	intact	10	no	32.50@90	53.50@180	NA		
20	5/60	nig			5/60	clear	1 loose suture	17	yes	39.0@90	51.0@180	52.0@167	39.0@77	606
21	6/12	nig			6/12	clear	intact	24	no	43.75@150	47.25@60	NA		
22	6/18	nig			6/18	clear	intact	16	no	42.25@70	48.0@160	NA		
23	6/24	nig			6/24	clear	intact	18	no	50.5@165	41.5@75	NA		
24	5/60	nig			5/60	stromal haze	9 loose sutures	12	yes	mires not clear		NA		
25	6/60		-2.0	180	6/12	clear	intact	NA	no	42.13@84	48.08@174	48.2@176	41.9@86	718
26	6/18	nig			6/18	Infiltrate inferiorly	2 loose sutures	14	yes	44.0@10	48.50@100	NA		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A Comparative study of the visual outcomes of penetrating keratoplasty and deep
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INTRODUCTION
Keratoconus is a non-inflammatory disorder characterized by ectasia of the cornea, most commonly the central or inferior portion of the cornea, with eventual progressive protrusion and corneal thinning.
The cornea, a clear transparent structure, is the major refractive surface of the eye. The corneal thinning and protrusion in keratoconus induces irregular astigmatism and myopia causing mild to marked visual impairment. The prevalence of Keratoconus is about 50 to 230 per 100,000 population.[1] Keratoconus usually has its onset at puberty and progresses until third to fourth decade of life[1] when it usually arrests.
Keratoconus is reported to have bilateral involvement in over 90 percent
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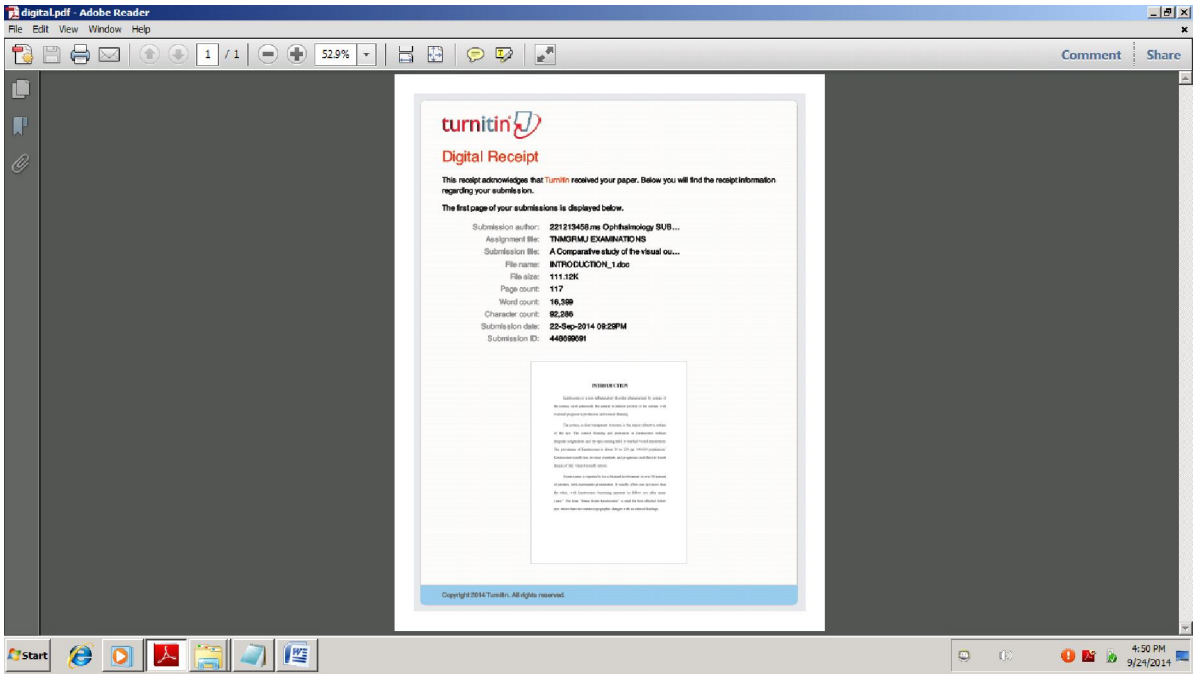
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INTRODUCTION
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